ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОЛОГИЧЕСКАЯ

PUBLISHED IN TRANSLATION BEGINNING
WITH THE 1958 RUSSIAN VOLUME YEAR.

IZVESTIYA AKAD. NAUK SSSR

SERIYA GEOLOGICHESKAYA

1961 — No. 10, October

CONTENTS

CHRONICLE

EDITORIAL COLLEGIUM

TWENTY-SIXTH YEAR OF PUBLICATION

Technical Editor - V. Ya. Karasev

T-11045. Approved for printing September 20, 1961.
Circulation - 3, 250 copies. Order 3947
Paper size 70 x 108-1/16 Paper 4 Printing sheets 10. 96+1 Publ. sheets 12. 7

Second printing office of the USSR Academy of Sciences Publishing House.
Moscow, Shubinskiy per., 10.

SOME GEOLOGICAL PROBLEMS CONNECTED WITH KNOWLEDGE OF THE INTERIOR OF THE EARTH[1]

by

D. I. Shcherbakov and G. D. Afanas'yev

The most important document of our time — the Draft Program of the Communist Party of the Soviet Union — points out that "progress in science and engineering under the socialist system of economy enables natural wealth and the forces of nature to be used most effectively in the interests of the people" and that "the use of science is becoming a decisive factor in the powerful development of the production forces of society".

The conquest of space, which has been developed intensively over the last few years, has led to amazing results. Modern engineering based on the latest achievements of science has served to promote it. As a result our knowledge of the Universe has advanced so much that it has far outstripped our present ideas of the structure of the interior of the earth. It is nevertheless the earth — our place of residence — which provides us with food and drink, and it is the depths of the earth which contain the variety of mineral resources which serve as the basis for the development of heavy industry and agriculture. That is why geologists in the coming era of Communism should be associated with the slogan "Let us conquer the interior of the earth! "

RADICAL CHANGES IN FUNDAMENTAL GEOLOGICAL CONCEPTS

The problem of what the earth is, how it came into being, what it was before, how it acquired its present appearance and became inhabited has attracted the attention of thinking people and excited their curiosity since ancient times. Tales of the origin of the world, or so-called cosmogony, invented by the ancient peoples showed their sketchy knowledge of the earth and the Universe. The cosmogonies were gradually replaced as time passed by more valid scientific views.

The geological science of the recent past was based on cosmogonic ideas which were conceived in the eighteenth century.

The philosopher Kant, and later the astronomer Laplace, advanced the hypothesis that the planetary system originated from a red-hot nebulus. According to their interpretation, the earth and the planets were once in a molten state, and then, having cooled, retained a molten nucleus. For a long time the Kant-Laplace hypothesis was part of the scientific world's outlook. In geology it became the basis of scientific formulations and conclusions with regard to the development of the earth. It lasted for all of the nineteenth and even part of the twentieth century.

The hypothesis of the molten stage, the gradual cooling and contraction of the earth gave rise to the theory of the fold formation of mountains, which was based on the idea of the contraction of the earth's core, onto which the surface crust settled, crinkling and rumpling. This hypothesis plus observations of an increase in temperature with depth in the earth's crust was the basis for the view that at a certain depth there was a magma capable of separating into separate molten layers as it cooled. Indeed it was this process which was used to explain the variety of magmatic rocks and the development of post-magmatic processes which led to the formation of numerous and varied mineral deposits.

Almost a hundred years ago the Austrian geologist, Edward Suess, first published his remarkable work. His generalizations, amazing for that time, covered the entire structure of the earth's crust, and he was the originator of a theory which reigned supreme among geologists for many years. He introduced a number of terms and concepts which have become part of everyday usage; for example, his definitions of the lithosphere, hydrosphere, the composition of the globe — "nife, sima and sial". In his celebrated book, "The Face of the Earth", (1883-1909) Suess attempted to view the earth from outer space by parting, as it were, the accumulations of dark red clouds and slowly

---

[1] O nekotorykh zadachakh v svyazi s poznaniem glubokikh nedr zemli, (pp. 3-12).

emptying the oceans and seas of their water. He pointed out the amazing depth of the oceanic basins, the low average height of the continents and their comparatively steep slope toward the oceanic depressions.

On the basis of the cosmogonic ideas of his time, he developed the contraction hypothesis which for a long time determined the trends of development of geology proper, and its branch — tectonics.

At the present time science is based on a completely different cosmogonic outlook, and this has also brought about changes in the fundamentals of geology.

We now postulate that the earth originated by densification of meteoritic matter, that it was therefore cold at first and that subsequent heating was due to a considerable extent to the decay of radioactive elements in protoplanetary matter.

According to these views, the earth itself generates heat. It is assumed that there is no molten core inside our planet, but that at a certain depth there is a maximum temperature layer wedging out at depth and toward the surface. On coming into contact with outer space the earth loses some of its heat, cools down and the heat conditions and pressure in the subcrustal layer or upper mantle determine, generally speaking, the observable oscillatory motion of the earth's crust.

There has not been a liquid layer in the depths of the subcrust for countless years; hence there could not have been any separation (differentiation) of it in the form in which it was imagined earlier. The uneven generation of heat in the upper mantle probably causes the matter to melt and partially shift to the higher layers of the earth's crust. It is precisely these processes which determine the distribution of matter — the formation, on the one hand, of a solid residue enriched with magnesium and iron, and, on the other hand, the emission of liquid and gaseous phases which concentrate a variety of metals.

THE PROBLEM OF OCEANIC DEPRESSIONS AND CONTINENTS

Despite the extent of his formulations and despite all their "globality", at that time Suess had no data on the relief of the ocean beds.

Nowadays we know that the bottom of an ocean is not an even, basin-shaped depression. We know full well that apart from first-order structural features — the continents and the bottom of the ocean — there are tremendous underwater ranges of the mid-Atlantic rampart type and so-called "island arcs".

One of the characteristic features of these formations is a deep central trench or "rift" stretching across the entire range, and, in the case of the island arcs deep-water depressions, situated side-by-side with the crests of uplifted areas. A second feature is that the present-day volcanos and earthquake epicenters are assigned to these formations. Whereas all of the epicenters of the mid-oceanic rifts occur at relatively low depths of the order of 30-70 km, deep earthquakes with epicenters 700 km below the surface are associated almost exclusively with the region of high-seismic underwater depressions and chains of islands surrounding the Pacific. The narrow graben-rifts seem to continue within the limits of continents or islands, and are therefore not exclusive to the ocean bottom.

These examples are sufficient to demonstrate the idea that at the present time it is not possible to divorce the tectonics of continents from the study of the structure of the ocean bottom. Hence, marine geology should be developed at a more rapid rate in the near future since the questions discussed above are undoubtedly among the problems this science must solve.

As is well known, however, the rapid development of remarkable geophysical research methods in the twentieth century has brought to light the fact that the continental and oceanic regions of the earth's crust vary considerably in the way longitudinal waves pass through them. At different depths below the oceans and continents there is a point of separation called the Mohorovičić, which is assumed by many specialists as the tentative boundary between the earth's crust and the underlying mantle.

The thickness of the earth's crust on continents ranges between 30 and 60 km, the latter being typical of mountainous regions where, according to geophysical data, the crust forms, as it were, scarps penetrating into the subcrust medium. In the actual crust there are two main layers — the upper crust which is said to be granite, judging from the rate elastic waves are transmitted through it, and the lower or "basalt" layer.

Under the oceans the structure of the earth's crust, according to the conventional interpretation of geophysical data, is different from what it is under the continents. Characteristic of the bottom of the ocean is the absence of the upper, so-called "granite" layer and the thin lower "basalt" layer. The Mohorovičić discontinuity lies comparatively close to the ocean bottom, at some points only 6-8 km beneath it.

The reasons for the difference between the levels of the discontinuity under the continents and the ocean are the basis for considerable discussion. The sum total of geological and petrological facts suggests that the difference is not

uestion of variation in the composition of the responding "layers", but the characteristics he physical state of the matter comprising earth's crust under the oceans and on the tinents.

The obvious conclusion to be drawn from this hat the solution of fundamental geological blems — the eternal enigma of the origin of earth's crust, magmas, mineral deposits, the reasons for catastrophic geological nomena — is possible if scientists turn their ention to the depths of the earth in the light of modern achievements of engineering and all ences associated with geology.

Scientists are becoming more and more conced that the reasons for the actual movent of the earth's crust, magmatism, volism and earthquakes are the sources of rgy and matter within the mantle. Of late, physical exploration has revealed a layer of luced velocities at a depth of the order of)-200 km (Gutenberg layer). This is highly bably inasmuch as this region of the earth's erior is one of magma formation and contration of the principal sources of energy. stances forming deposits of a great variety minerals rise from this region together with magma, causing volcanic eruptions and astrous earthquakes.

ROJECT TO STUDY THE UPPER MANTLE

In view of the tremendous interest now being wn by geologists in the study of the deepng regions of the earth's crust, in the nmer of 1960 the Assembly of the Interional Union of Geodesy and Geophysics pted a plan to organize extensive geophysical l geological exploration of the top of the shell, earth's mantle, and its relationship and sociation with the earth's surface. The plan s named the "Upper Mantle Project". Conlerable effort will be required on the part of umber of scientific-research organizations well as individual scientists from many untries to complete it.

An International Organization Committee, aded by the President of the I. U. G. G. and rresponding Member of the Academy of Sces of the U. S. S. R., V. V. Belousov, was ganized to coordinate the research, to work t basic recommendations and to plan the prot as a whole. National Committees are being ganized presently in a number of countries to rry out the work envisaged for the project. e most rapid and practical way of testing ether or not the mantle lies deep below the ttom of the ocean is to carry out drilling erations from ships through a 4-km layer of ter.

According to the latest information, in March, 1961, the U. S. A. began an experimental drilling in deep water with a view to testing the equipment and machinery which might later be used to carry out the so-called Project Mohole. The ultimate aim of the project is to drill through the earth's crust beneath the ocean to determine the composition and physical properties of its layers.

Experimental drilling operations are going on in the region of Guadalupe, off the northwest coast of Mexico, through 3570-meters of water. The operations are conducted from an unanchored ship, the position of which is kept constant by a system of engines, at a point whose coordinates are latitude 28° 59'N and longitude 117° 30'W.

The region of the drilling was reconnoitered before the operations were begun: echo soundings were made, samples of the bottom were taken and seismo-acoustic sounding was carried out, showing that the bottom consisted of loose sediments, 150 m thick, strewn with rocks.

The drilling is being carried out by the standard rotary method used on dry land in the oil industry. The main aim of the drilling is to establish the stresses and strains acting on the ship and the drill casings under experimental conditions, and to determine the optimum speed of rotation of the drills and the requisite weight of the drill. The drill core is the only thing which connects the ship to the ocean bottom, hence if at any time it is drawn up, it will be impossible to find the hole again. This means that all operations with the drill core, measuring and sample-taking have to be carried out by means of instruments lowered into the drill core from the ship or by cable. A diamond drill is used for the job, irrespective of whether the rock to be drilled is hard or soft. By April, 1961, a depth of 186 m below the ocean bottom had been reached, and a basalt core brought up from this depth.

A sample of the core, sent as a gift to the Academy of Sciences of the U. S. S. R., underwent a preliminary investigation at the Institute of Geology and Mineral Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences of the U. S. S. R. Microscopic study showed that the core was augitic basalt, possibly even diabase; was fine-grained and contained SiO_2 = 48. 40%, NaO_2 = 1. 20%, K_2O = 0. 33%; specific gravity, 2. 904.

An attempt was made to determine the absolute age of the rock by the K-Ar method. The following data were obtained: content K - 0. 28%, Ar^{40} in hmm^3/g = 0. 0024. The age was 212 ± 10 million years. To calculate the age it was assumed that: $\lambda_k = 0.557 \cdot 10^{-10}$ $years^{-1}$. $\lambda_\beta = 4.72 \cdot 10^{-10}$ $years^{-1}$. The age tests were carried out at the Institute's Laboratory by L. L. Shanin.

Taking the low potassium content into account, it should be kept in mind that the accuracy in determining the age is not very high. At any rate, the age of this basalt, provided there have been no superimposed processes to distort the true ratios of the parent rock and decay products, is close to 200 million years, which corresponds to the Triassic. Although we do not know the total section of the drill core, we hardly think that a 186 m column could unearth a continuous series of geological formations ranging from the present-day back to the Triassic period inclusive.

The rate of accumulation of oceanic sediments, as proved by one of us in an article written in 1960[2], and as has been shown by Ericson, Ewing, Wollina and Heeven,[3] is considerably greater than would follow from accepting the continuity of a section ranging from "today down to the Triassic" represented by a column 186 m long.

It is more likely that there is a discontinuity in the sequence revealed by the drill core and that the position of the top of the section does not tally with the bottom, including the Triassic basalts.

It should be pointed out that the age of the Palisades diabases determined by Ericson and Kulp by the K-Ar method[4] is close to that of the basic rock from the core of the deep-water hole (190-200 million years).

PROBLEM OF STUDYING THE DEPTHS OF THE EARTH ON CONTINENTS

Now as never before the aim of our geologic science is directed toward an understanding of the structure of the earth's crust, elucidating the interrelationships between the mantle and the earth's crust, studying the development of deep magmatism, and getting to know the processes of differentiation of terrestrial matter. Twentieth century geologists realize that the structural features they observe on the top of the earth's crust and its endogenic phenomena reflect processes which are going on at tremendous depths.

The structure of the earth's crust in the continental regions and the deep-seated processes occurring in it have so far been ascert ed only to a slight extent because of the inaccessibility of these regions to direct observat Study of the structure of the depths of the ear crust and the laws governing its development, cluding the periodicity of geological processes should be a joint study for geologists, petrologists, geochemists and geophysicists, acco panied by an experimental research program special drilling operations to a maximum dep in carefully selected regions.

Many aspects of the problem in question, s as the geophysical study of the deep structure the earth's crust and mantle by seismic sounc ing, study of gravity anomalies and the drillir of super-deep holes should be carried out by geophysical and industrial organizations coupl with geological research on the problem. But the interpretation of geophysical data and the selection of the drilling regions is definitely a matter for the joint efforts of geologists, petr logists and tectonic experts.

The participation of vulcanologists and hyd geologists is also important, for they, togeth with the geologists, petrologists and tectonic specialists, can undertake to study the deep-seated heat of the earth's crust and throw ligh on the laws governing present-day volcanic eruptions.

This study of the earth's crust is particula important to the scientific establishments of t Division of Geologic and Geographic Sciences of the U. S. S. R. Academy of Sciences in orde to explain laws governing the origin and devel ment of magmatic processes and their close link with tectonic and ore-forming processes. Close attention should be given here to "Magmatism and its link with the deep-seated struc ture of the earth's crust in the formation of commercial minerals".

Knowledge of the evolution of the material which the earth's crust is made through the ge logical history of our planet is the basis of the geological theory of magmatic and ore-formin processes and is absolutely essential at the present stage of the development of geology w its national economic slant towards scientific forecasting of deposits of the most important commercial minerals in the earth's crust.

Radiological study is one of the most important ways of solving this aspect of the prob lem. After all, the solution of many radical theoretical problems of the geological history the earth and the evolution of its shell involve the construction of a geochronological scale a the establishment of the absolute age of geolo cal, and particularly magmatic, formations b the U-Pb, K-Ar, Rb-Sr and other methods.

The main trends for research on this prob are:

---

[2] G. D. Afanas'yev, The petrographic interpretation of geophysical data on the structure of the earth's crust, Izv. Akad. Nauk. S.S.S.R., ser. geol., No. 7, 1957.

[3] D. B. Ericson, M. Ewing, G. Wollina, and B. C. Heeven, Atlantic deep-sea sediment cores. Bull. Geol. Soc. America, vol. 72, No. 2, 1961.

[4] G. P. Erickson, and J. L. Kulp, Potassium. Argon dates on basaltic rocks. Ann. N. Y. Acad. Sci., vol. 91, art. 2, 1961.

ı) magmatism and the deep-seated struc-
: of the earth's crust on the basis of study
he different-aged and different-type (basites,
abasites, granites and alkaline rocks)
rographic formations for different geostruc-
ıl regions of the earth (platforms — folded
ions) and detailed study of their content, in-
ling the physical properties of rocks com-
ssing the magmatic complexes. The latter
articularly important for a correct inter-
tation of geophysical data.

) The genesis of igneous rocks on the basis
xperimental studies of silicate systems at
ı pressures, with the participation of
tile matter, and a study of the geologic-
rographic development of magmatism in the
th's crust in regions having different geo-
onic structure. Here, particular attention
uld be given to the oldest and deepest-seated
ks — eclogites and drusites, for example.

:) Study of the relationship between mag-
ism and endogenic mineralization on the
ls of a combined geologic, petrographic and
chemical study of magmatic formations and
r derivatives aimed at developing a scientific
ls for forecasing the occurrence of com-
rical minerals.

l) Radiological study of rocks with a view
eveloping an absolute geochronological
le and learning the specific nature of the
ıposition of rocks by means of isotopes and
r contemporary methods, coupled with
ing the inter-relationship between the for-
ion of rocks and derivative post-magmatic
cesses.

These studies should provide results in the
n of summary monographs on the following
or problems in geology.

ı) The evolution of magmatism in the earth's
st through study of the development in space
time of the natural associations of igneous
ks and the experimental study of petro-
esis.

) Magmatism and tectonics on the basis of
int study by tectonic experts and geophysi-
s of the structural development of geosyn-
es and platforms, and study of problems
ı as the geology of the ocean bottom and
anic islands.

:) The physical (including elastic) properties
ocks and minerals of different natural
ociations.

l) Variation in the properties of rock-form-
minerals as a function of the composition,
ditions of formation and effect of super-
osed processes.

) The effect of petrogenetic processes on
the disruption of equilibrium states in radioactive elements and their decay products in minerals used to determine the absolute age of rocks and as tracers for geochemical and ore-forming processes.

STRUCTURAL SUPER-DEEP BORINGS

Everyone knows of the progress made by Soviet geologists, engineers, technicians and miners in building up a stock of minerals and raw materials in our country. But the next few years require a very great increase in the mining of all types of minerals and a complete record of all of their reserves in the earth.

A dynamic change in our fuel balance through an increase in the specific gravity of oil and gas, planned by our Party and Government also necessitates deeper penetration of the depths of the earth than before. Practice shows, after all, that apart from the Tertiary oil-bearing rocks, the Mesozoic and older Paleozoic deposits are extremely promising from the point of view of their oil and gas content. But they often lie at depths between 4000 and 10, 000 m.

About 20 years ago an important project to drill structural or stratigraphic wells was begun in our country; by now this has almost been completed. These holes have given us a clear idea of the structure of the uppermost part of the earth's crust and have played a major part in the advancement of oil geology which supplies the country with oil and gas.

The next stage of deeper penetration by man into the depths of the earth to bring up the wealth hidden there, first and foremost, the oil and gas, is now at hand. Success in this extremely important project is closely associated with the completion of super-deep drilling to a depth of 10 or 12 km or more, which will provide us with precise knowlege of the structure of deep-seated layers. In order to reach the deep oil and gas we must be able to drill deep and super-deep wells inexpensively. These are required both for prospecting and for the actual extraction of the oil and gas.

Furthermore, deep wells will undoubtedly reveal new mineral deposits, so far unknown.

Deep drilling will give us the chance to utilize the heat in the depths of the earth, which would bring about a saving of millions of tons of fuel every year. At the same time, super-deep wells would enable us to study directly the composition of the rocks and their physical properties, including density, elasticity and viscosity. This will enable us to make substantial corrections to the quantities used in calculating the velocity of seismic waves and other geophysical characteristics, and this will lead to improvement in geophysical calculations and

make them much more reliable. Hence geophysical methods and they are many times cheaper than direct drilling, will become even more important than at present and will promote our study of the depths of the earth.

Super-deep wells are therefore absolutely essential for formulating present-day geological theory which should combine processes occurring in the depths and the reflection of them near the surface. Without them and without knowledge of the structure of the depths, geological theory will make no progress.

The deep holes should be drilled not only in the ocean, but also on the continents, since this, from our point of view, is more promising for the solution of urgent problems. The contacts discovered in the earth's crust corresponding to velocity differences in elastic waves at levels down to 10 or 12 km can be studied within the Baltic or Ukrainian shields. Knowledge of the structure of the earth's crust and the reasons for the deep divisions in these sectors will enable us to go on to a more ambitious program, including drilling the bottom of the ocean.

Progress in this field will help the advancement of the second important problem in contemporary geology, which is the "establishment of laws governing the formation and location of commercial minerals in the earth's crust", this will enable us to construct metallogenic charts and maps from which to correctly forecast the occurrences of commercial minerals.

TECTONIC MAPS

Just as before, in the nineteenth century the geological map, which reflects the structure of the earth's surface and the relative age of the geological formations composing it, is still the basis of the practice and scientific reasoning of geologists.

The geological map is a very important link in geological work between theory and practice. Without these maps there could not have been any projects to expand the stocks of minerals and raw materials in our country, to increase water resources or to carry out the present-day large-scale construction. At the same time, the geological map is widely used for forecasting commercial mineral deposits and for geological theory.

The present-day geological map, however, does not adequately explain the relationships existing between rocks in space and time. Thus a need has arisen for special tectonic maps of the structural features of the upper part of the earth's crust from the standpoint of their development. These maps are, as it were, a graphic explanation of the geological map and supplement them to a considerable extent.

The compilation of tectonic maps of continents is a new way of summarizing the work carried out by an enormous number of geologists studying the earth's crust. These maps which cover very large continents, which differ in structure, are first and foremost a basis for theorizing with regard to tectonic development. By studying the arrangement and relationship between the structures of different ages and types, we can obtain an idea of the movement of the crust in its different sections.

When looking at them, for example, one is struck by the rectilinearity of many of the boundaries between structurally-different regions and the angularity of the outlines; this shows the major role played by deep-seated faults in the structure of the earth's crust, not always marked by surface disruption. Our most eminent tectonic experts consider that the different histories of the tectonic development of the Pacific and Atlantic segments of the earth's surface are most clearly brought out by a map.

Thus, tectonic maps are absolutely essential for understanding the structure of the earth's crust, solving the principal problems of theoretical geology and selecting sites for deep drilling.

Tectonic maps are at the same time, of great practical importance. They can be used to compile metallogenic maps and maps for forecasting the occurrence of commercial minerals. Experience gained by all geological institutions in compiling metallogenic maps shows that they must contain basic data on the age of folding, the distribution of different structural stages in each zone of folding, the arrangement of specific tectonic forms (folds, faults) and, finally, the structural position, age and composition of intrusions. Thus, apart from compiling small-scale tectonic maps covering as much territory as possible, we should strive to produce large-scale tectonic maps of different parts of the U. S. S. R.

Tectonic analysis of the bottoms of seas and oceans adjoining the U. S. S. R. should be a vital part of the study and mapping of the tectonics of the U. S. S. R. in the future.

EXPERIMENTAL STUDIES

The organization of experimental research is essential in dealing with a number of problems involved in the study of the depths of the earth's crust. Among other things, experimental physical-chemical mineralogy and petrography, which should in effect serve as the theoretical basis for the study of commercial mineral

osits and prospecting, is not being adequately eloped.

Unfortunately, in the U. S. S. R. there are no oratories like the Carnegie Geophysical oratory in the U. S. A., and the lack of it kes itself felt in all branches of our geologi- science. Some of the physical-chemical and neralogical work in our country is done in oratories and institutes which are not marily intended for geological study. An mple of this is the comparatively small In- ute of High Pressure Physics; it has well- ipped workshops which are used for studying synthesis of individual minerals.

Thus, the U. S. S. R. Academy of Sciences st step up its work in experimental miner- gy and petrography by setting up a special tor in the I. G. E. M. and, later on, by ablishing a special institute within the Geo- ic-Geographic Sciences Division.

This sector should engage in the experi- ntal and thermodynamic investigation of blems in mineralogy and petrology, the elopment of the physical-chemical theories mineral formation on the basis of experi- ntation, and the analysis of natural mineral agenesis.

The subjects for experimental research uld include:

a) Development of methods of determining nperature and pressure in natural processes ineralogical geothermometry and geomano- try).

b) Experimental study of the filtration effect.

c) Experimental simulation of metasomatic cesses.

d) Study of the properties of silica melts avitational stratification, degree of ioniza- n, microheterogeneity, transmagmatic solu- ns).

e) Crystallization of melts at constant rtial pressure of mobile components, de- ndence of eutectic and cotectic compositions the regime of mobile components and addi- es; acid-basic interaction of melt components.

f) Study of mineral systems at various pressures and temperatures.

g) Connodes between minerals of varying composition as functions of temperature and pressures; extreme states.

h) Thermal constants of minerals.

i) Acid-basic interaction of components in aqueous solutions.

j) Oxidizing-reducing potentials during natural processes, and their relationships to acidity-alkalinity.

k) Transfer of all components in aqueous solutions.

l) Variation in isotopic composition during mineral formation.

* * *

This list of some of the problems of contemporary geology is based on the view that the path ahead of geology will be difficult unless geophysicists and geochemists combine their efforts in the extensive development of experimental research and penetration deep into the earth's crust.

Study of the depths of the earth will make it possible to substantiate and formulate a new geological theory, opening up fantastic possibilities in the utilization of mineral resources.

There is no reason to doubt that the earth reacts as a cosmic body to outside effects by varying its speed of roation and tilt of the axis of rotation to the ecliptic. Tidal effects occur on the earth and give rise to internal friction which, in turn, affect its rotation.

These extraneous factors, being of cosmic order, have all undoubtedly affected the geological development of the earth and the processes taking place both on and within it. The aim of discovering the relationship between the earth and the cosmos by geological methods should be the basis for close collaboration between geology and the sciences studying the Universe and the earth's neighbors in the solar system.

SOME IMPORTANT PROBLEMS IN THEORETICAL GEOLOGY[1]

by

A. V. Peyve, N. M. Strakhov, and
A. L. Yanshin

The amount of the various minerals used by man will be substantially stepped up within the next 20 or 30 years. Both qualitative and quantitative progress in this field will be so extensive that normal progress of industry and power engineering will not be possible without radical advancement in the knowledge of the distribution and formation of mineral masses of different composition in the lithosphere. Thus, before long the earth sciences will be faced by new and tremendous tasks which at the present time they are not adequately prepared to deal with.

Soviet geology with its variety of branches has made major theoretical achievements, reviews of which have frequently been published in the press. There is no point in merely enumerating these achievements. We need only to point out that the comparative abundance of various types of mineral resources today is due to a considerable extent to the progress of theoretical geology in our country.

The names of Academicians Karpinskiy, Vernadskiy, Fersman, Levinson-Lessing, Gubkin, Arkhangel'skiy, Zavaritskiy, Smirnov and Shatskiy will go down in the history of science as the names of prominent scientists who have been able to combine profound elaboration of problems with the solution of specific and practical tasks. The discovery of rich iron deposits in the Kursk magnetic anomaly, oil in the Second Baku and the Cis-Caucasus, diamonds in Yakutia and many other valuable mineral deposits, was based on scientific forecasting and a sound knowledge of different geologic and geophysical laws.

An outward sign of the advancement of Soviet theoretical geology is its rapidly increasing influence on the development of world science. At sessions of the International Geological Congress and other international conferences, reports by Soviet geologists are playing a leading role more and more every year. Monographs, papers on methodology and even magazine articles by geologists of our country are being translated and published both in the People's Democracies and in France, Britain and the United States. Soviet scientist are becoming the initiators and leading lights in such international projects as the compilati of a tectonic map of Europe.

These undisputed achievements, however, do not mean we can relax, and, what is more, the light of the present reorganization of scientific activity in the country they should even be regarded as quite inadequate.

In geology there are still many more unkno unclear and disputed questions than ones which have been exactly explained. The general the of geologic processes is only in its infancy, ar even then, only in certain fields, for example, lithology. Our views of the structure of the depths of the earth, the reasons for tectonic movements, the processes of metamorphism c rocks and the mode of formation of many minerals are often still mere hypotheses.

This is mainly due to the inadequate theoretical research conducted by our scientific institutions; in many cases there has been no material-technical base for extensive and varied analytical and experimental research, without which hypotheses cannot be confirmed.

The progress in Soviet geologic science mentioned above has been principally the resu of theoretical endeavor by a handful of talente people. Most of the members of geologic institutions have remained aloof from profound theoretical work. This situation is the result the overall development of geological work in our country.

Before the First World War there were too few trained geologists in the country, the network of outlying geological institutions was still underdeveloped, and many regions of the country had not been properly studied. Under these conditions, both outlying industrial

---

[1]Nekotorye vazhneyshie zadachi v oblasti teoreticheskoy geologii. (pp. 13-20).

entific institutions and those in cities l to devote a great deal of attention to specific actical problems raised by the requirements the national economy. At the request of a riety of organizations the Academy of Sciences ganized expeditions for combined geological dy of different parts of the country. Most of trained personnel of the Academy took part these expeditions and most of the funds signed for geological research were used to ance them. In carrying out their program geologists of the Academy of Sciences did a eat deal of good in developing the country's ional economy, and in a number of cases, by ocessing the materials they collected, carried valuable theoretical work, though most of m were obviously unable to devote much attion or effort to the important theoretical oblems.

During the war, of course, all the manpower l funds were used to meet the requirements the front lines and the country's defense.

During the post-war years, tremendous oretical research was begun in many branches science and resulted in the harnessing of mic energy, the conquest of outer space, and er achievements which heralded a new era in history of man. In geology, however, the organization took its time and the lesser probns of the day continued to occupy the attention the Academy's scientific institutions, alugh at present such problems easily could be ndled by branch institutes of various Minises and their departments. Even at the present time, many of our scientists are showing a rtain trepidation in raising and tackling oretical problems, the solution of which could ve a tremendous practical effect on the future.

As a result, with respect both to equipnt and apparatus, and to trained pernel, the scientific institutions of the Geoic-Geographical Sciences Division of the ademy of Sciences have proved to be inadeately prepared to solve important theoretical oblems of the earth sciences. It is quite ear that the situation which has arisen in the velopment of its theoretical fundamentals ist be changed. This applies, first and foreost, to the institutions of the Academy of Scices of the U. S. S. R.

In its generalizations, Soviet geology must far beyond the bounds of the Soviet Union in years to come. It must analyze material om other countries and publicize natural laws a global nature. This will undoubtedly lead a radical reappraisal of a number of fundantal views in stratigraphy, tectonics and ner branches of geology.

Within the Soviet Union the era of ore prosction on the surface of the earth is drawing a close. The search for deposits buried deep underground is being widely developed. Within the next few decades the search for deposits and their exploitation will reach ever greater depths. This means that geology must devise methods of finding concealed deposits, invisible from the surface, for which both geophysical and geochemical research methods and those of other branches of geology must be improved, for without them neither geophysics nor geochemistry can provide a single answer to the problems posed. Much more detailed stratigraphy than is practised at present and much more accurate methods of facies analysis and paleographic formulation are required to prospect for buried minerals; we must make big strides forward in studying formations and in the general laws governing the origin and location of commercial minerals.

There is no doubt that during the next few decades the extraction of minerals from the bottoms of seas and oceans, which cover 71% of the surface of our planet, will be extensively developed. Soviet oil specialists have already moved far out to sea in the Caspian, and so have American oil experts in the Gulf of Mexico. They will be followed by geologists in search of other types of minerals. Both the exploitation of minerals from recent sediments (for example, manganese concretions on the underwater plateau in the Pacific) and the ancient minerals in the zone of low-water shelf seas will be items on the agenda. This means that there must be a more thorough geological study of the sea and ocean bottoms and the origin of the oceanic depressions.

The application of geology to the national economy will also be extended. In view of technological advnacement, the utilization of types of minerals which are for the moment unexploited will become profitable. New spheres of application will be found for minerals required only on a small scale at present. This means that geology must encompass the study of the overall composition of the earth's crust so as to be able to meet the requirements of the national economy, whatever they may be.

The time is coming when extensive use will be made of the energy of geologic processes, first and foremost, heat. The hot waters and vapors which we are only just beginning to use in the sphere of present-day volcanism (Kamchatka, Kuriles) will be employed at other places, too, where they lie within reach of the drill. Completely new problems in using power may arise in connection with super-deep drilling and the attainment of the deeper shells. In view of this, we must study the earth's heat balance and investigate the shelfs. Research of this kind can be conducted by the joint efforts of, geologists, geophysicists and geochemists. It will probably be 10 or so years before they are widely developed, but they will nevertheless occupy in the future one of the most important places in the earth sciences.

Geology cannot remain aloof from the progress of the study of the earth as a cosmic body, or other cosmic bodies. The progress in study of the earth along these lines should be used to reappraise existing views on the movement of the earth's crust and its tectonic structure. A study must be made and an evaluation given of the possible effect of cosmic phenomena of the past on the development of the organic world. Investigation of the structure and the history of other heavenly bodies should also be developed.

These fields of investigation are not the same from the point of view of their present state of development and the prospects of further development. It is quite obvious that study of the inner layers of the earth will be developed somewhat later than research in other directions. Nevertheless, the present rate of development of science enables us to speak confidently of the genuine need to commence work in all of the mentioned fields.

Let us take a closer look at some of the topical problems of contemporary theoretical geology.

Most pressing in the study of the material composition of the sedimentary shell of the earth's crust is the different types and different stages of sedimentary rock formation — sedimentogenesis, diagenesis, epigenesis and metamorphism. Broad theoretical research has already been carried out on the humid and arid types of sedimentary origins, although there is no doubt that it could be continued, particularly from a geochemical standpoint. On the other hand, the theory of the effusive-sedimentary type of rock formation has been little studied by either Soviet or world science. It is indeed in this field that we can expect great discoveries in the relationship between endogenic and exogenic factors in the formation of a number of mineral concentrations, very important in practice (phosphorus, aluminum, iron, copper, lead, vanadium and other elements).

Many of the genetic problems of present-day lithology, essential for practice, and varied and large-scale forecasting cannot be dealt with without profound study of the effusive-sedimentary type of sedimentary process or without appropriate assessment of the endogenic depth factor as a whole in sedimentary rock formation or in the formation of the salt composition of seas and oceans.

In view of this, further study of effusive-sedimentary formations of the past and the laws governing their formation is vital. Such research should explain first and foremost the processes of mobilization, migration and concentration of matter in volcanic zones active at the present time, the effect on them of climate and the part played by volcanism in forming certain mineral concentrations. The dependenc of these phenomena on the tectonic situation should also be studied.

Further, in lithology a very interesting prob lem is the study of facies-genetic relationships between dispersed elements and accumulations of their ores. In recent time, problems of the sedimentary accumulation of humid and arid zones have been widely publicized in Soviet lithology, hence we can not go on to elucidate the theoretical fundamentals of the geochemical processes occurring in humid climates. This should be the basis for study of migration, the distribution and accumulation of different elements in tropical, sub-tropical and moderate climates in different facies of sediments.

A key to these processes could be elucidation of the paragenesis of elements, particularly minor elements and rare earths, both in bauxite, iron and manganese deposits, phosphorites and carbons, as well as the parent rock deposited under different circumstances.

The next most important problem is to study the important transformations which rocks undergo in their geological history during epigenesis resulting in a considerable regrouping of rock components. A study of these processes would enable us to bring to light the facies of regional epigenesis, to note the difference between this process and metamorphism and to ascertain the part it plays in forming a number of epigenetic mineral deposits. But of particularly great importance is elucidation of the geological history passed through by the rocks from the moment they were formed to the present time. For this purpose, it is very important to expand the laboratory methods of studying the physical properties of minerals since this will enable us to make the constants of mineral modifications forming in different environs more accurate.

Finally, an important problem in the study of the material composition of the sedimentary shell of the earth's core is the evolution of the sedimentary process throughout the history of the earth; the study should be made on the basis of knowledge of the types of lithogenesis.

There is no doubt, however, that in the history of the earth both the quantitative relationship between these types and the qualitative nature of the processes inherent in various types of lithogenesis have changed. This is why there are "extinct" rocks and sedimentary formations, and this fact is extremely important in establishing the regularities governing the location of commercial minerals.

In the study of magmatism the main emphasi at the present time is on deciphering the phsica chemical side of the process of deep mineral

rmation and rock formation. Very extensive d improved experimental research should be ganized in this field. With regard to the rely geologic study of magmatism, there is greater need than ever before for joint solu- ns of a number of problems.

The general regularities governing mag- atism coupled with knowledge of the deep ructure of the earth's crust, the distribution space of natural associations of magmatic cks as a function of major tectonic struc- res of the earth's crust, the geochronology of agmatic phenomena and the evolution of the agmatic process throughout the history of the rth are all general geologic problems which n be dealt with effectively in conjunction with ose of geochronology and geotectonics.

As is well known, geology is a historical ience. One of its main aims is to determine e history of events which occurred on earth the course of geological time. So far, the storical sequence of events in different parts the globe has been reconstructed by the bio- ratigraphic method based on analysis of the placement of organic forms with time. It is nsidered that the replacement of fauna occurs most simultaneously in different parts of the obe. On the other hand, geology now widely nploys methods of determining the absolute e of rocks by study of the isotopic composition radioactive elements. But the use of this new ethod, which for the moment only assigns tes to the relatively larger periods of time nsufficient for geological practices) has posed number of new problems for science. In rticular, it has turned out that certain stages geologic history are extremely uneven in rms of absolute age, whereas geologically eaking they are the same. A tremendous nount of factual material has been accumulated the present time, enabling us to study the lationship between absolute and relative geo- ronology, to ascertain the accuracy of the ne scale used in geology, and to solve the oblem of synchronism or asynchronism of ratigraphic units on different continents. This ct will provide a sound basis for the historical construction of geological events of the past d the factors govening the geologic evolution the earth.

This work will naturally give rise to new ethods of stratigraphy and, therefore, im- oved methods of geologic mapping, so very sential for practical needs.

The relationship between the absolute and lative times in geology can be illustrated most early by the example of the study of the young- st Quarternary (Anthropogene deposits) by dis- overing the relationship between the geochrono- gy of its sedimentary accumulation and the aciation taking place in Anthropogene time. ne Elucidation of these relationships, just as the features of Anthropogene time as a whole, will help to link the present with the past and will, in effect, be a key to earlier geologic history. This research is of great methodological and scientific importance.

During this research, which can be carried out only by composite use of classic biostratigraphic and geomorphologic methods in conjunction with physical and geochemical methods, the most important stages in the development of Anthropogenic fauna, flora and man in the geologic history of the earth will come to light. Among other things, such research will throw light on the appearance of man of the contemporary type in the Paleolith, the origin of Quarternary mammalian fauna and of flora in the Eopleistocene in Europe, and will also show the specific features of the development of marine and continental fauna in Siberia and the Pacific.

The synchronism or metachronism of climatic variation and associated glaciation in the Northern Hemisphere should be studied at the same time by drawing general conclusions from the data available on Europe and Northern Asia, using physical methods and comparing them with data for North America and with variations in the levels of the world ocean.

In the case of the more ancient deposits the most important problem is accuracy in the presently accepted comparisons — the absolute or relative simultaneity of processes occurring on the globe, — of the epochs of folding, transgression and regression, sharp variation in the organic world, climatic variation, and so on.

The solution of these problems, which used to be based on paleontological data, always rested on the vagueness of the relationships between the development of organic forms in different biogeographic provinces and geotectonic regions. At the present time, physical methods enable us for the first time to find certain reference points for correlation between different biogeographic zones. Hence, we must concentrate on the problems of the biogeographical zonality of the geologic past, using data from isotopic and paleontological analyses, and date the more important events of the geological past more accurately. This will definitely lead to a final solution of the age-old problem of exact synchronization of stratigraphic subdivisions and will clear up a number of general problems of the paleography of the earth's surface.

We can already characterize the botanic-geographic zonality of the Northern Hemisphere, discover the features of the Upper Paleozoic flora of the Angara region and their relationship with those of other provinces, describe the zonality of Jurassic, Cretaceous and Paleogene flora in the Northern Hemisphere, as well as map the position of climatic zones in the geographic past more accurately.

Further research along these lines would enable us to ascertain the relationship between the stages and nature of the development of organic forms in the basins in different geotectonic regions and biogeographic provinces (the problem of synchronism and homotaxality), and for the first time in present-day conditions there is a possibility of assessing both the effect of local or regional factors and that of factors on the development of organic forms of planetary importance, which can be ascertained by comparing the stages of development of organisms from the Pacific, Atlantic and Mediterranean provinces during different epochs.

Apart from its general theoretical importance, this work is vital to an understanding of the limits of the stratigraphic subdivisions, methods of substantiating them and their retention in space, which is essential for the further development of present-day stratigraphy and geomapping.

Geologists urgently require a considerable broadening of their present views on the history of the earth's surface over the centuries and further elaboration of the problem of geologic time and the development of the earth's crust in the Precambrian.

Until recently the history of the earth's crust had been studied in any detail only for its last 500 million years. Use of data on the absolute age and problematic organic residues (stromatolites, etc.) now provides us with the preconditions for expanding geologic history another 1-1/2 to 2 billion years, during which the principal tectonic elements of the earth's crust took place. This research in effect creates a scientific basis for harnessing the mineral wealth of the axial zones of structures and depths of the earth, and will at the same time bring to light the characteristic features of the oldest stages of the earth's development, linking geology to astronomy and making it possible to talk of the stages of the development of the earth in terms of a planet.

This aim is to be attained by expanding research in absolute dating of sedimentary sequences of the Precambrian, ascertaining the relationship between the absolute age data and processes of sedimentary accumulation, different in the Precambrian and Postcambrian ages, and throwing light on the development of organic forms from the preserved traces of their existence. This can be used as a basis for understanding the history of the earth's crust in the Precambrian and of the mode of appearance of the principal tectonic elements of the earth's crust.

The structure of the lithosphere and its tectonic life are in particular need of thorough study, since our knowledge in this area is still very restricted even though it would determine the development of all the earth sciences as a whole, the origin of the earth, its structure an development.

A very important problem which can be solved by the comparison of tectonic maps of the continents and oceans is the study of spatial and temporal regularities in the positioning of the earth's fundamental structures.

At the present time, by virtue of the great accuracy and degree of detail in mapping geologic structures of all the continents, we are in a position to discover the general geostructural laws governing the arrangement, shape, size, mutual combining and coupling of different structural elements which, in the final analysis form a sound structural picture of the earth, rather than a chaotic one.

An urgent problem is the study of the block structure of the earth and the associated study of different tectonic lines providing a distinct structural picture. Deep faults and other lineaments, folded arcs, virgations, "end" joints, criss-crossing structures, and so on, should be studied on an infinitely more accurat geological basis and on a planetary scale.

Clarification of the relevant regularities would be of exceptional interest since it would provide us with the key to the greatest mystery of tectonics — the origin of the fact of the earth

Another aspect of this problem is the questi of the temporal regularities of tectonic development: tectonic stages, cycles, phases, their causes and significance. This is associat with the division of the folded regions into the Caledonides, Hercynides, Mesozoides, and Alpides; the distinguishing of more or less com pletely repetitious tectonic cycles; the idea of dividing the history of the earth into the Proterozoic, the Neogene, etc.

This group of temporal regularities governing the development has long been of exceptiona importance in tectonics. At the same time the is an urgent need for a critical reappraisal of all the relevant regularities in the light of new facts and new methods of analysis.

The second problem governing the level of development of all the earth sciences and the cosmos is the movement of the earth's crust. At the present time this problem is being studied without reference to cosmic factors or to the conditions of the earth's cosmic existenc The development of geophysics, geochemistry, astronomy and geology in the fields of geostructural laws and laws governing the shifting of blocks in the earth's crust throughout geolog time, may provide new solutions to the age-old problem of the reasons for tectonic movement.

Over the last few decades, on the basis of

ing geologic and physical methods of investi-tion, the branch of geologic and geophysical ience which concerns the deep structure of e earth's crust, the forces, tensions, move-ents and sources of energy, has been rapidly veloping. Such problems play a large part in e development of a number of branches of geo-ysics, for example, seismology and gravi-etry. Hence, the problem of the relationship tween deep and surface structures is an ex-emely urgent one, and will help us to under-and the genesis of tectonic formations, to sess the part played by horizontal com-ession and elongation in forming the struc-re of the earth's crust, the origin of mag-atism, earthquakes, etc. To solve such prob-ms as that of the structure of the subcrustal yers and the origin of oceanic depressions, e U. S. A. has worked out some expensive ojects for super-deep drilling down to the se of the earth's crust. The need for exten-ve development of geologic-geophysical re-arch enabling us to establish the relationship tween the surface and deep structures of the rth's crust and to determine the mechanism formation of tectonic structures is acknowl-ged both here and abroad.

In view of this, we think it is absolutely sential to organize a specialized institute the study of the deep zones of the earth's ust which could unite the efforts of geophysi-sts, geochemists and geologists in different lds studying the composition and structure of e deep-seated regions of the earth's crust and bcrustal shells. In an institute of this kind illed engineers could make plans for super-ep drilling while experienced heat engineers uld weigh the possibility of using energy from e depths of the earth. So far, we do not have any institute of this kind, although without it we are not in a position to solve problems of conquering the depths of the earth successfully.

Research on the enumerated problems would throw light on the cardinal aim of the earth sciences and the cosmos, namely, the structure and development of the earth as a whole and, as a result, would answer, to some extent, the question of the nature of the zonal structure of the terrestrial globe and the overall evolution of its shells — mantle, crust, hydrosphere and atmosphere.

The comparative characteristics of the structure and development of the lithosphere and the solid shells of other planets and evaluation of the effect of cosmic phenomena on tectonic, paleogeographic and biological processes occurring on the earth would also be part of this fundamental aim.

The elaboration of these problems will be a precondition for the development of research on man's conquest of the minerals and energy hidden in the depths of the earth.

Geological Institute of the
Academy of Sciences of the U. S. S. R.,
Moscow

Received, 20 June 1961

CONTEMPORARY GEOLOGY AND ITS PLACE IN THE NATURAL SCIENCES[1]

by

Ye. V. Shantser

The tremendous advancement in the natural sciences during the twentieth century is primarily due to the impressive progress in physics and chemistry which has made them a sound basis for all of the natural sciences. This development has not left out geology, either. New physical and chemical methods are being incorporated more and more into its various branches, providing greater possibilities for scientific research. The "borderline" disciplines such as geophysics and geochemistry have come into being and are being rapidly developed, and have already made it possible to discover a number of important regularities in the structure of the earth and the history of the materials composing it. It has now become possible to gain an objective idea of the properties of matter in the deep shells of the globe – the mantle and core – which used to be completely inaccessible for study by conventional geological methods. Our knowledge of the earth's present and past has moved way ahead, and new prospects for a deeper understanding of it have opened up.

It is in this connection that over the last few years the question of the importance of geology and the prospects of its development and its independent place among the other natural sciences has become a subject of lively interest.

Geology evolved as an independent branch of the natural sciences during the second half of the seventeenth century when society's needs for crude ores began to grow as a result of incipient large-scale capitalist industry, accompanied by an increased interest in the depths of the earth. Since that time geology has undergone complex development. There has been a gradual increase in the range of subjects studied, as well as changes in the methods and aims, and hence an accompanying change in the essence of the science.

The first so-called "heroic" period in the history of geology was essentially the period of accumulation of the basic factual material and the development of basic methods of geologic observation. Originating from mining, descriptive mineralogy and "geognosy", on the one hand and older physical geography on the other, the new-born science of geology retained in toto the formally descriptive nature of these disciplines. The establishment and primary systemization of observed facts were its main aims. The extremely scanty resources of the latter and the lack of any set methods of truly scientific research limited its possibilities, which amounted mainly to a simple description of the properties and mode of occurrence of rocks. Naturally, even at that time the wondering mind of the naturalist was not satisfied by the narrow, formally descriptive framework. Historical development, organically inherent in all geological occurrences, made itself felt and geologists were inevitably faced with the complicated problems of the origin of rocks and ores, and hence the origin and past history of our planet. There is nothing therefore surprising that in the eighteenth century a tense ideological struggle developed between the opposing school of Neptunists and Plutonists, a struggle which involved radical problems of the earth's past and present. Nevertheless, the ideas of Werner's doctrine of Neptunism, which dominated the times, basically were not gleaned from geological facts themselves or a scientific analysis of them, but from the natural philosophical concepts of past thinkers. Their sources were the views of Decartes and Leibnitz revived in the middle of the eighteenth century by Buffon and later diluted with a large dose of biblical teaching. It was indeed the lack of generally-accepted and reliable methods of scientific analysis of geological data plus the attitude and theory of the educated bourgeous society of the time to Jacobite free-thinking and materialism of the French Revolution that caused the defeat of the truer teachings of Hutton and his disciples which bore the seed of materialistic and evolutionary ideas.

From the beginning of the nineteenth century the range of interests of geologists shifted to the realm of paleontological stratigraphy and to

[1]Sovremennaya geologiya i yee mesto v estestvoznanii. (pp. 21-35).

building the basis for geologic chronology. But geology merely acquired the semblance of a historical science thereby, and basically remained at the formally descriptive stage of development. It had not yet been enhanced by truly scientific methods of historical-geological analysis.

The paleontological stratigraphy of the time, which was more of a profession than a scientific discipline, could serve, therefore, only as a basis for the entrenchment of the deeply metaphysical teaching of catastrophism, the originators of which, including the eminent scientist J. Couvier, simply could not see its obvious contradiction of the facts known at the time.

The transition to the second "classical" period in the history of geology was accomplished between the 'thirties and 'fifties of the nineteenth century. It was marked by the victory of evolutionary ideas, associated with the names of Lysle and Darwin. This was the era of the first truly scientific principles of historical-geologic research when evolutionary paleontology and the modern method were gradually becoming the chief tools in geology. Despite the certain crudity and inefficiency of the methods of the time, they helped geology to change from a formally descriptive science to a historico-graphic one, the main purpose of which was the documentary reconstruction of the chronicles of geological history. True, the level of actual knowledge limited its possibilities principally to reconstruction of events which had occurred in the past on the earth's surface, but the development of morphologic-tectonic research methods and microscopic petrography gave some idea as well of the development of the internal structure of the earth, though only at the very top of the crust.

The end of the nineteenth and beginning of the twentieth century heralded the turning point in the history of geology. The development of capitalism and its transition to the new, imperialist stage promoted exploitation of the earth's interior on an ever-increasing scale and the incorporation of more and more virgin territory into world economic ties. In all of the leading countries there were developed geological services which systematically carried out geological and survey work. In the guise of pioneers of imperialist expansion, numerous geographical and geological expeditions penetrated deep into all continents. A mining industry grew up amid the most remote and sparsely populated deserts and tropical forests. This produced a flood of new factual data, and rapidly broadened the outlook of geologists. For the first time it became possible to conceive of the structure of the whole crust as a whole, and the abundance and variety of the new data encouraged the adoption of comparative methods in all fields of research. The science of geology entered the third stage of its development, gradually changing into a science which was predominately a comparative-historical study aimed at discovering the general laws governing the historical development of the earth's crust as a whole on the basis of extensive empirical generalizations, and at throwing light on the qualitative characteristics of the subsequent natural stages.

At the same time, the increase in the variety and complexity of the problems tackled and the new research methods intensified the already started process of diversification in geology. A series of new, more or less independent disciplines gradually took shape, and some of the earlier ones were broadened or changed in nature. For example, the generalizing work of A. P. Karpinskiy, J. Děnn, E. Suess and E. Oga marked the birth of historical tectonics, the studies of I. Walter, L. Dollo, N. I. Andrusov and other scientists founded the sciences of lithology, paleogeography and modern biostratigraphy. The comparatively monolithic science of geology had formed a complex set of subsidiary sciences.

In the twentieth century, geology, just as the natural sciences as a whole, began to develop more rapidly than before. The first theoretical generalizations were followed by new ones, which often corrected or even refuted them in many respects. Many of the earlier, firmly-held views began to crumble. This was particularly obvious in the field of theoretical tectonics.

The new data on the structure of the earth, even from the first few decades of the century, made it more and more obvious that the old contraction theory in the classical form, as formulated by Eli de Beaumont, no longer held water. It began to be replaced by more and more geotectonic hypotheses, unilateral and mutually contradictory for the most part, so that in the twenties and thirties, as so wittily put by C. Longwell, tectonics began to resemble a "madhouse". Somewhat later, again at times in extremely dynamic form, the collapse of earlier views began in other branches of geology as well; for instance, a heated controversy arose regarding the origin of granites, which still goes on to this very day. All this is an indication that the descriptive-empirical basis on which geology was founded throughout the preceeding periods in its history had become too unsound and was incapable of solving the new, cardinal problems of the earth's history.

The need to change from the simple statement of empirically establishable laws to a genuine explanation of their causes and discovery of the fundamental laws of the earth's historical development is becoming more and more of a topical problem. But the solution of these intricate problems is inconceivable if

study is merely limited to the thin crust enveloping the earth. It is quite clear that the transformation of its structure is not unrelated to changes occurring in its depths — in the mantle and core. On the contrary, it is just there that the main sources of the energy of the endogenic processes underlying such highly important and decisive historical and geological events as mountain formations, folding and magmatism are to be found. For geologists the mere framework of the earth's crust is too narrow already the subject of geology includes; the structure and development of the globe as a whole. It is thereby changing from the science of the earth's crust to the science of the entire globe.

Geological research methods in their classical form are no longer adequate to cope with the new problems. They need improving, rejuvenating and augmenting with new, more effective, more perfect ones.

Whereas the science of geology was once able to make do with knowledge of the exterior aspect of geological processes and manifestations, we now require deeper penetration into the interior structure, first and foremost by discovering the physical and chemical nature of factors motivating them. Hence the very development of geology leads logically to the need to incorporate physics and chemistry in the solution of cardinal problems. This is not only becoming essential, but also possible, and solely through the progress made in these sciences themselves; their theoretical level, the methods and equipment used in them have now reached the stage at which they are capable of active participation in solving the complicated problem of geology, rather than just specialized, restricted problems, as was the case in the last century. It is therefore understandable that it is the twentieth century that has given rise to the new and extremely fruitful "borderline" sciences of geophysics and geochemistry. In this respect, geology is no exception to the other branches of natural sciences, particularly biology, the development of which is also marked by the appearance of the "borderline" physical- and chemical-biological disciplines in the twentieth century (biochemistry, biophysics).

The above-mentioned factors have given rise to the specific features of modern geology which probably distinguish it from the geology of the beginning of the twentieth century just as much as the latter differs from the "classical" version of the second half of the last century. Modern geology, or, rather, the group of geological sciences which it has become, is now going through a period of stormy development and reconstruction, marking the advent of a new, higher stage of development, a new, fourth period of its history in which there is a transformation from the earlier descriptive-empirical sciences, into an explicative, genuinely theoretical science which views the earth as a single unit and studies all aspects of life on it in their close historical interrelationships, thereby uniting within itself all the individual sciences of the earth, many of which study only individual aspects of the present state of the globe, inevitably divorcing one from the other. From this standpoint, all these scientists, no matter how important or strictly limited their aims and research methods may be, work to some extent for the good of geology. Geology is thus the nucleus around which the general teachings of the earth are united.

Not all its disciplines are interrelated to the same extent. Some of them — those which study the present state of the earth's surface and the outer shells, the hydrosphere and atmosphere — are developing with a relatively greater degree of independence from the geologic disciplines proper. It is not so much the laws of internal development of the earth which are particularly important to them as the interrelationship between its peripheral geospheres and the factors of the cosmic medium, first and foremost the flow of energy from the sun (meteorology, climatology, etc.). This is fairly good reason to combine them into a separate cycle of sciences with a geographical slant in the broadest meaning of the word.[2]

But the disciplines which study the structure, composition and historical development of the earth's internal geospheres, — the crust, mantle and core — are so closely intertwined that none of them can be treated as a sphere of knowledge unrelated to geology. On the contrary, together they form an organic entity which should be understood as modern geology. In this entity there merge, not only the old, so to speak, "the root", geological sciences (mineralogy, petrography, lithology, tectonics), but also practically all of the so-called "transitional" and "intermediate" biological-physical and chemical-geological sciences.

It is only paleontology which occupies a special position among the latter because its leading divisions, which deal with the systematics and evolution of extinct organisms, are so closely interrelated with biology that they can justly be regarded as a part of it. But they, too have developed historically from geology and primarily serve the practical side of geologic research, while their theoretical tenets, for the most part, are unthinkable without extensive use of geologic data and research methods.

[2]The question of the essence of geography as such and its position in the natural sciences as a whole, and among the earth sciences in particular, has been intentionally omitted here. It is a subject which deserves separate discussion, even if only because geographers themselves have not reached a unanimous opinion on what geography is.

Still more closely associated with geology are paleoecology and particulary paleobiogeology. Both in subject, and in methods of study, they are inseparable from lithology and biostratigraphy, being conventional divisions of historical geology. These disciplines are, in fact, geologic rather than biologic in the proper sense of the word.

As regards geophysics[3] and geochemistry, an objective analysis of the problem shows convincingly that these, too, are indivisible parts of modern geology. They are united to the other geologic sciences first and foremost by the generality of the subject and the aim of the study — the structure and development of the earth as a whole. The distinctive nature of the subject and its aims are determined as well by the specific methods of scientific investigation employed in these disciplines. They combine organically physical and chemical methods on the one hand, and purely geologic ones, on the other. In the theoretical field geophysicists, and particularly geochemists, are obliged to think not so much in terms of purely physical and chemical categories, as in geologic categories. Inasmuch as the position of geophysics and geochemistry in the system of earth sciences is disputed, we will come back to it again at a later stage, when the specific nature of geologic phenomena and geologic processes, which is of very great importance in assessing the basis of geology as a science, has been analyzed.

The action of often extremely numerous and varied physical, chemical and biological factors underlies every geologic process. The complex and sometimes deceptive forms of combination and interaction of these factors throughout the millions and billions of years that the earth has existed are usually quite accidental from the purely physical, chemical and biological standpoint. Hence, they cannot be adduced as the direct and essential corollaries directly implied by these sciences. But they are quite justified if approached from the historical-geological point of view and considered in the light of causes and effects which are revealed by study of the development of the earth's crust or the globe as a whole, except that in this case every geological process has a strictly defined place in the overall system of change in the face and structure of the earth; only then does its geological role and the true historical reasons for its existence become understandable. In other words, it is only then that we discover the specific geological laws which certainly cannot be reduced to individual physical, chemical or biological regularities determining the action of individual processes. Hence the study of the physical, chemical and biological nature of these motivating factors alone is often insufficient both for understanding the part played by geologic processes in the development of the earth and for simply singling them out and classifying them. The more complicated the process under consideration, the more sharply is it delineated. This is fairly clear even in relatively simple cases.

Let us consider for a moment a simple example — the activity of waters flowing over land. From a purely physical, or rather, hydrodynamic point of view, any flow of water, from a small stream of melted snow or rain water to a large river, flows according to very similar laws, if not identical ones and the mechanical work which these flows dc also conforms to the same physical laws. It would seem that there are exclusively quantitative differences between them, and that the historical-geological part played by streams and rivers, on the one hand, and streams of melted snow and rainwater trickling down mountains, on the other, differ qualitatively. Rivers and rivulets cause linear erosion in the proper sense of the word. They cause deep ravines and valleys on the land's surface and separate the watershed elevations between them, or, in other words, they subdivide the land surface and make it more uneven. Each stream of rainwater or melted snow taken separately, as it flows downward, also strives to make its own cut or tiny gulch, which at first sight differs merely quantitatively from the large ravines and valleys caused by major rivulets and rivers. But the overall effect of this activity of a dense network of streams is the process of areal erosion to the point of a more or less uniform reduction of the surface of the slope and the development of a gentle slope. The erosion caused by rivers and rivulets dissects the land and increases the degree of uneveness. Areal washout smooths out the relief, reduces its contrast and levels the land surface. The difference between the geologic result of erosion and areal washout shows up as well in the formation of basically different genetic types of continental deposits — alluvium which fills the bottoms of valleys and deluvium which covers the bottom parts of the slopes. These are completely different geological bodies which in typical cases differ sharply both in shape and in mode of occurrence, internal composition and structure.

This is a splendid example of the dialectic law of change from quantity to quality. But here it is of importance to us from another standpoint. After all, if we merely studied the physical aspect of the factor — the mechanical work of flowing water — we would never be able

---

[3]This means only the geophysics of the crust and depths of the earth. This a completely separate field of knowledge, the combination of which with the physics of the atmosphere and hydrosphere into so-called "general geophysics" is quite artificial.

to assess the extent of the qualitative difference between these two processes. It is only the study of geologic results to which they lead over long periods of time and only a historical-geological assessment which enables us to pinpoint their difference in principle, to shed light on the roles which they play in the historical development of the earth's surface and to note the specific nature of their development.

Let us look at another, much more complicated case — sedimentary ore formations. As has been proved most conclusively by N. M. Strakhov [7] in his recently published book on the theory of lithogenesis, the formation of sedimentary ores, including iron and aluminum deposits and cuprous sands, is the result of the same processes as the deposition of ordinary sedimentary rocks. But in order to realize this the joint action of a whole number of favorable factors governed by the geologic situation at a given time and place was required.

Strakhov distinguishes a minimum of five such factors: 1) heightened intensity of the chemico-biogenic melt of the ore component in the given sea or lake; 2) favorable hydrodynamic conditions and paleogeographic position of the reservoir and its ore-forming region; 3) slight dilution of the sediment with terrigenous material transported from the shore; 4) the additional concentrating effect of the redistribution of matter in the diagenesis of the ore deposit; 5) erosion of the ore body with removal of the finely-dispersed terrigenous material.

The direct action of each of these five factors can be explained by fairly simple physical and chemical laws which enable us to reconstruct the mechanism and dynamics of the accumulation of each specific ore deposit and the pattern of the accumulation dynamics of all deposits of a corresponding type. But this far from exhausts the geological laws for the formation of sedimentary ore deposits as a whole, determining their spatial and temporal localization throughout the geologic history of the earth's crust. Nevertheless, it is only by discovering these general geologic laws that we can understand the possible distribution of deposits of this type, and, consequently, learn to prospect for them and make reliable forecasts for the future. This can be done only by analyzing the specific history of the earth's crust and surface, by showing in which geological eras and in which regions the relief, climate, shape of the land and sea combined to produce a favorable combination of these factors. Naturally, in the long run, the occurrence of these conditions is the result of a long chain of complex, interrelated physical and chemical factors. But it is inconceivable in practice that we could reconstruct this entire relationship by physical and chemical research methods or bring to light the causes and effects of individual links. As anyone can see, geological methods alone are suitable for this.

This concerns to a much greater extent such complex categories of phenomena as magmatism and folding. Physical and chemical laws only help us to understand separate details and individual processes making up their composition, or, conversely, certain extremely general premises for their appearance. It is impossible to ascertain the specific reasons and thereby explain the origin of the types of motion of the earth's crust, the types of tectonic deformation, the emplacement of magmatic intrusions of a certain composition and shape, etc., at the given place and in the given geological epoch, merely by physics and chemistry. To do this correctly we must know the specific laws of development of the crust and the earth as a whole, determined so capriciously by a combination of different factors, that without specialized geological methods or on the basis of chemical and physical data alone they cannot possibly be established, just as it is impossible to deduce them directly from the general laws of physics and chemistry.

It is only by a close, organic union of physical, chemical and biological methods with geological methods that it becomes possible to find a complete and thorough explanation of the laws of development and present-day state of the earth, and thereby master the laws and adapt them to human needs. Here the importance of geological methods must not be underrated by assigning them an auxiliary, second-grade role, as some people try to do, referring to their allegedly descriptive nature. It must be kept in mind that it is these sciences which contribute the element of historical background, without which knowledge of the past or the present of the earth is unthinkable. It is just this profound historical background which is a specific feature of any geological study, including physical and chemical-geological studies, and which distinguishes it basically from the conventional physical and chemical studies, which are mainly restricted to the present state of matter and the continuous, yet transient and reversible changes which describe it.

In the given sense the historical background of the study is important to us from two different points of view. First of all, a geological phenomenon can be understood only through knowledge of its origin. Most geological processes are extremely slow, taking many thousands, millions or tens of millions of years. Hence they do not lend themselves to experimental reproduction or simulation. Nor do the complex geological environs, varying as they do, in time, in which the particular process occurred. Thus, the most important way of reproducing the actual course of the process has always been and still is the geological method. The stratigraphic sequence of stratification, the study of structural relationships between minerals composing rocks and ore deposits, etc., all enable us to single out the natural stages of

the process and determine its chronology. Study of the occurrence of rocks, their interrelationship, the organic sediments within them, and the nature of their deformation sheds light on the medium in which the process developed and on its variation with time. Only by a knowledge of the specific geological situation can we decide on the correct material for study of the physical and chemical properties of matter, the aim of experimental research and the conditions for its successful solution. On the other hand, geological inspection of the physical and chemical data obtained alone can ensure an objective check on the validity of the conclusions.

A second, equally important aspect of geological history is the irreversibility of changes of the state of the earth and its crust. The development of the globe as a whole is irreversible, just as the stages of development of all individual geological features are to some degree irreversible. The history of the earth is an advancing process, during the course of which its structure, its physical state and the thermodynamics and physical-chemical environs in its depths and on its surface also change qualitatively. The conditions for the processes and the course itself change accordingly. Discovery of the laws governing this forward, irreversible development is the principal task in studying the earth both in theory and practice.

As an illustration we can refer to the well-known works of Strakhov [5, 6] on the evolution of sedimentary iron ores and carbonate rocks.

It is indeed by means of geological methods that in his work he reveals the specific development of the irreversible changes in the two processes, helping us to understand the distribution of a number of minerals in variously-aged deposits.

The study of the chemical composition of a mineral and its physical-chemical mode of occurrence plays a great part, of course, in this research. But the general laws of chemistry and physics, valid for nature as a whole, are in themselves insufficient to explain the causes of these irreversible changes or to enable us to deduce laws governing them. For this purpose we require a specific analysis of the actual course of history, a leading place in which is occupied by geological methods.

Thus, the incorporation of physics and chemistry into geology in no way reduces the importance of the specific methods employed by the latter, but merely enhances it, raising it to a high level. This is due primarily to improvement of the geological methods themselves through the acquisition of new physical and chemical methods. A good example is the method of facies analysis of sedimentary rocks, the foundations of which were laid back in the middle of the last century. For a long time this method was based on simple analogy between minerals and present-day deposits similar in composition, on the one hand, and on the study of the biologic community of extinct organisms found in rocks. These characteristics were used to judge the mode of formation and environs of rocks. At the present time the organic element in facies analysis is a thorough physical-chemical study of the rock material and laws governing its change in space and time. Coupled with this profound study of the physical-chemical nature of present-day geological processes, this has improved the possibilities of the method and made the conclusions reached by means of it more reliable and definite, and in effect has turned it into a new, improved method. The same thing can be said of the petrography of igneous and metamorphic rocks. This science is incorporating physical-chemical methods more and more extensively, including experimental research, thus revolutionizing it, supplementing it and enhancing an old microscopic method.

The second form in which physics and chemistry have invaded the realm of geology is the birth of new "borderline" disciplines — geophysics and geochemistry — in which physical and chemical methods play a leading part. Nevertheless, these, too, should, certainly not be regarded simply as applied branches of physics and chemistry. On the contrary, as has already been stressed, they are an inseparable part of present-day geology and their fruitful development is unthinkable if they are divorced from it.

This is particularly clear from the example of geophysics, although it is the geophysicists themselves who cry out in favor of the total emancipation of their science from geology. The physical methods of studying the earth possess a number of undisputed advantages. At the same time, however, their possibilities are strictly limited, at least in two very important respects. Firstly, they enable us only to assess individual physical constants of matter, which in themselves are totally inadequate for reliable and unified conclusions on its composition, or even physical properties as a whole. Secondly, they enable us to study only the present-day state of the globe i. e., they lack the very element of historical background which has been discussed above.[4]

It is just for this reason that if the physics of the earth is divorced from geology, it is only able to give a very general and incomplete picture of the present state of our planet, and

---

[4]Methods of radiometry based on the study of the results of irreversible processes of decay of unstable atoms may be, to some extent, an exception.

cannot provide a successful solution to historical-genetic problems.

The interpretation of physical data on features of the structure of the earth's crust is always made in conjunction with geological data and is guided and controlled by the latter. The close unity of physical and geological methods is a feature of the scientific geophysical method as such, distinguishing it from physical methods in the true sense of the word. This is clearly shown by geophysical prospection. But even here the origin of tectonic structures and ore deposits discovered by geophysicists is entirely a matter for geologists.

At first sight a major role is played here by the paleomagnetic method, which has become very popular in recent times. Many people consider it, and not without good reason, as one of the important methods of directly solving such complex problems in the history of the earth and its past as precession or of the horizontal movement of continents. Even in the given case, however, we are concerned not only with the study of residual magnetism of rocks by purely physical methods, but by the close link between this study and extensive general geological investigation. Even the choice of material for paleomagnetic study stems from geological considerations — the age and origin of rocks. The end results and their degree of reliability are determined to a still greater extent by geological facts, for they cannot be formulated with any degree of validity without being coupled with paleogeographic data of the past brought to light by the conventional methods of historical geology. Not only that, there is good reason to believe that it is only a thorough analysis of paleogeographic data that can enable us in the long run to overcome the serious discrepancies which have arisen in interpretation of paleomagnetic observations, to reconstruct a true picture of the evolution of the earth's magnetic field and to shed further light on its nature and origin.

Such is the situation in the application of geophysical methods to study of the upper part of the earth's crust. Regarding the deeper-seated zones, and especially the mantle and core, geophysics is the only source of information on their structure. The use of conventional methods if absolutely out of the question. Yet it is for this reason that we know so little of the geospheres and have not been able so far to reach any single conclusion on the composition and state of the materials making them up. Some indirect information is provided by astrophysics and planetary astronomy, although these are based on hypothetical assumptions with regard to the origin and development of the planetary bodies as a whole, which in themselves require verification. More reliable, although, naturally, also tentative conclusions can be derived by extrapolation of direct geological observations of the structure of the earth's core and composition of the rocks comprising it. The fact that these data are given a geochemical interpretation does not affect the matter, since this interpretation is based entirely on facts discovered by geological methods.[5]

It is not surprising that the geologist E. Suess had the honor of devising the first complete and substantiated plan of the inner structure of the earth. Even to this day the plan has retained far more than just historical interest and has been improved and supplemented rather than discarded by subsequent study. All of the characteristics of the composition of internal geospheres which are used in scientific literature at the present time (basalt, peridodite, eclogite shells, etc.), have been completely borrowed from data obtained by geologists on the composition and laws governing the distribution of rocks in the earth's crust. Thus we can understand the great hopes which have been placed on the experimental drilling operations already begun on the continents and ocean bottoms. These alone can make it possible for us to make a direct study of the basalt layer, and maybe the upper parts of the mantle by geological, including geochemical, methods and to move from speculation to firmly established fact.

Naturally, the possibilities of directly drilling down to great depths are extremely limited, hence geophysical methods of investigation will continue to occupy a prominent place in the future. As they are gradually perfected, they will enable geophysicists to bring to light the structure of the internal geospheres in ever greater detail; this has been confirmed by the entire experience in the development of geophysics.

Until very recently the earth's mantle was represented as a shapeless, homogeneous mass. The progress made in seismology has now forced us to abandon this idea. Data on deep-focus earthquakes prove convincingly the inhomogeneity of the structure of the mantle to a depth of at least 700-900 km. We can be sure that in the future it will be possible to ascertain details of the internal, undoubtedly rather complex structure, to single out the deep tectonic structures of various types in it and to establish laws governing their spatial distribution. But in order to understand the history of these structures, only one path is open — the elucidation of their relationship with the more

[5]Information on the composition of meteorites used for the same purpose is no exception, since it is based on mineralogical-petrographic study of these heavenly bodies, i.e., on study by geological methods, on the geology of meteorites and not on their astronomy.

perficial structures in the earth's crust, the story of whose development has been documentarily reconstructed by geological methods. is only by considering the history of the crust d mantle together as two inseparable zones at we can deduce the basic laws governing it. order to do this geophysics must become an tegral part of geology as a group of interlated sciences, and geophysical methods ust be a synthesis of physical and geological ethods. For if it is detached from geology, ophysics cannot provide anything but a static scription of the structure of the globe, i. e., simple description although one cloaked in ysical-mathematical form.

The close association between geochemistry d geology is much more obvious and undisited. Therefore there is no need to dwell on the oof of it in so much detail, and we will make ly a few brief comments. If we exclude the w, very general laws governing the material mposition of the earth directly implied by the ructure of atoms and ions, all of the remaing problems of geochemistry can be resolved an equal extent by chemical and geological ethods proper. It is precisely this synthesis at is the characteristic feature of geochemil study and makes it different from chemistry.

Furthermore, geological methods are very ten of decisive importance to geochemical oblems. After all, we can only know the ws of migration, paragenetic combination d concentration of chemical elements in the rth by knowing the physics and chemistry of ch category of geological processes, such as eathering, diagenesis, metasomatism, metaorphism, magmatism, etc. We have already en above that the actual classification of these ocesses is possible only by using broad, genal-geological methods. It is especially geogical methods which enable us to distinguish tween the results of these processes ocrring in the past and preserved in the bowels the earth in the form of rocks, minerals and tural associations. Hence fruitful geochemil research enabling us to establish the ecific laws of evolution of terrestrial matter possible only as an integral part of generalological research. Methods of facies alysis, paleogeography, magmatic petroaphy, tectonics, etc., are not so important chemical and physical-chemical methods oper. And the point, of course, is not who its them into practice, whether the geochemist the geologist; but that the results are utilized the geochemist. No matter how this probm is solved, geology continues to be the main llar of support, and loss of contact with it evitably results in the loss of geochemistry's wn power, just like the legendary Antaeus when rn away from Mother Earth.

Thus, geophysical and geochemical methods studying the earth may serve as an effective tool for discovering the specific laws of development, first and foremost because they are a synthesis between physical and chemical methods proper and geological methods. It is this fact that makes geophysics and geochemistry historical sciences in keeping with the subject and aim of their study, and at the same time determines their separate existence as aspects of modern geology, rather than as purely armchair physical and chemical disciplines.

The earth is a single, systematically constructed material system, infinitely more complex than the fields or elementary particles which are encountered in physics and chemistry. These forms of the motion of matter are an essential precondition for the appearance and development of the earth as a whole and all of the particular geological phenomena and processes which are inherent in its specific nature. Their complex combination which occurs throughout the geological history of the earth in different forms gives rise, however, to new laws of development of the earth, which do not lead directly to the general laws of physics and chemistry. Their existence sways us, in B. N. Kedrov's opinion [3] toward the fact that the community of geological processes and phenomena forms a special, qualitatively different, form of motion of matter, higher with respect to physical and chemical forms, the dielectic unity of which is its basis. This geological or planetary form, as G. L. Pospelov calls it [4], describes the stage of development of matter which is widely represented in the universe by planetary bodies and is not limited to the earth alone, and therefore takes on great importance as one of the fundamental forms of motion alongside physical, chemical and biological forms. The latter is an offspring of the geological form of motion, which serves as a precondition for its origin and inevitably gives rise to it under certain conditions at a certain stage of evolution of the planets. But having once evolved, the biological form of matter remains inseparable from geological forms, is part of it and becomes one of the geological factors in determining the origin of a number of peculiar regularities governing their development. Hence, from the moment life began on the earth, the specific laws of the latter's development express the complex dialectic interaction of both the physical and the chemical and biological forms of the motion of matter. Naturally, in order to understand these laws we must apply physical, chemical and biological methods of study, inseparable from each other and from specialized geological methods. It is indeed this unity which is becoming an ever more characteristic feature of present-day geology, and one of its manifestations is the birth and development of "borderline" physical, chemical and biological-geophysical disciplines.

The progress in physics and chemistry during

the twentieth century had an active effect on geology, helping it to get outside of the narrow framework of a science of the earth's crust and to enter a new stage of development in which it gradually changes into a composite science of the structure and development of the earth as a whole, and of the overall laws of the geological form of motion of matter. Geology is gradually losing its former countenance as a descriptive discipline, having discarded it to a considerable extent at the preceding stage of transformation into a comparative-historical science. As it gradually acquires physical and chemical ideas and methods, geology is assuming features bringing it closer to these exact sciences. This is evidenced, among other ways, in more and more extensive use of mathematical apparatus for solving geological problems and in the fact that number and measure are gradually replacing the former purely qualitative characteristics. But this does not take away from geology its specific nature, determined by its qualitative distinction as a science. The historical background of study continues to be its principal distinguishing feature, and at the same time its importance and the specific methods of geology are retained in their entirety, only the form being changed and the content being enriched by the addition of methods borrowed from physics and chemistry.

In order to understand the relationship between modern geology and the other natural sciences correctly, we should remember, first and foremost, that the overlapping of sciences, typical of our age, is not a one-sided process. This also applies to the invasion of geology by physical, chemical and biological ideas and research methods. This has not only enriched geology, but has also had a great effect on the development of physics, chemistry and biology. Knowledge of the essence and mechanism of geological processes which take place slowly, over the course of millions of years, and unfold in conditions differing sharply from those reproduced by ordinary laboratory experiments, enables us to determine physical, chemical and biological laws which would otherwise have escaped the investigator or be misunderstood. Indeed, such an important branch of physics as crystallography, for example, is an offshoot of mineralogy, an inseparable part of geological science. It is indeed the study of the crystal structure of minerals that made it possible to bring to light the internal structure of solid matter which then became the basis for the present theory of solid state physics.

Crystallography gave birth to crystallochemistry, one of the most important branches of modern chemistry, which to this very day continues to glean new facts from the field of mineralogy.

It is not an exaggeration to say that the understanding of many aspects of the brittleness, plasticity and fluidity of solids has been greatly furthered by geologists' observations of rock deformation occurring over long periods of time under pressures and at temperatures which cannot be completely reproduced in laboratories even at the present time. There is every reason to believe that a profound study of tectonic deformation can help us to solve many important problems of rheology in the future. Just as important to chemistry is the study of the course and results of the slow processes of interaction between the so-called "weak" chemical reagents, examples of which abound in geology. Would it really be possible to correctly evaluate the chemical part played by water in nature, for example, if we did not know about the hydrolysis of silicates and alumosilicates slowly occurring during the weathering of rocks and leading at times to the total decay of apparently incredibly stable chemical compounds? A large part in developing the theory of chemical interaction in the solid state is to be played by observations which are already commonplace in geology. Many examples could be given. As for biology, we need only point out the fact that the study of the geological history of the organic world and its link with the change in habitation conditions in the geological past can alone help us to cope with a number of cardinal problems in the theory of evolution.

Thus, geology is by no means a passive recipient of the achievements of the so-called "fundamental" sciences and biology, but also is an active participant in their own development. But in assessing the relative role of all these three extensive branches of natural science, the specific nature of geology distinguishing it sharply from physics and chemistry should be kept primarily in mind.

Physics and chemistry study the relatively simple forms of movement of matter, characterized first and foremost by their universality in nature. These forms of movement underlie the existence and development of any complicated material features and phenomena. This is why the laws established by physics and chemistry are universal laws of nature, without knowledge of which it is not possible to develop any branch of the natural sciences. From This point of view physics and chemistry can truly be called the "fundamental" sciences. Naturally, their advancement is determined, first and foremost, by the possibility of rapid progress in the natural sciences as a whole, including geology.

Geology studies the considerably more complicated form of movement of matter inherent in a certain class of large material systems — planetary bodies. This form of movement is manifested universally in the world, and, in the main, is a synthesis of the simpler physical and chemical forms of movement from which it is derived. Hence the laws established

ty geology do not have as universal an importance as those of physics and chemistry, and discoveries in geology cannot basically affect the natural sciences as a whole to the same extent, particularly physics and chemistry, the deductions in which underlie actual geological research. The effect of geology on the other natural sciences is restricted to more particular, sometimes even more substantial aspects of their development.

That is why we cannot expect achievements in geology which could compare in importance with the revolution in physics during the twentieth century. This revolution was brought about by the cognition of completely new, hitherto unknown forms of motion of material and the laws governing them, which have a still more universal importance than the old laws of classical physics. The discovery of elementary particles and processes of interaction as well as the mutual transformation of mass and energy, the development of the theory of relativity and quantum mechanics heralded the birth of a completely new branch of natural sciences linked to the "classical" physics by little more than tradition. Geology studies one specific type of movement of matter and geologists do not aim at going beyond it, at least as long as their sphere of interest is restricted to the earth. Hence, revolutions in geology of the same kind as in physics should not be expected. From this point of view, we partly agree with John Bernal [1], who said that nothing has occurred in the twentieth century which would be reason for a radical reappraisal of the geological principles laid down in the nineteenth century.

Nor can we expect a reappraisal of this kind in the future, not even in the "classical" realms of physics which have been unaffected by the revolution of the twentieth century.

But Bernal is wrong when he concludes from this that geology has come to a stop and practically exhausted its possibilities in the field of theory. We have already seen the tremendous changes which have taken place both in its methods and in the type of problem with which it deals. These changes have meant that the old names and terms now possess new concepts and that the entire content of geology is different. And from this point of view, its principles are by no means unchanged, and it has by no means stagnated as a whole, but, on the contrary, is developing more rapidly than before and without doubt is on the verge of great, new discoveries.

The laws established by geology, of course, are less universal and therefore not so "fundamental" as those of physics and chemistry. But this does not mean that they are of subsidiary importance to mankind. In this respect, the position of geology is close to that of biology. Biology also studies one of the partial higher forms of movement of matter, for the moment only known reliably on the earth. Its laws are therefore not more universal, but probably less so, than those of geology. Nevertheless, there is hardly any one who would dispute the tremendous importance of the biological sciences, which are rightly considered the most importance branch of the natural sciences.

Study of the earth is one of the most important aspects of cognition of the world and one of the ways man can conquer his natural environment. Hence the earth sciences have always been of both general-theoretical and practical importance. And in the future, their place, particularly that of geology, will undoubtedly be even more important, for the all-embracing use of the natural wealth of the world and the reorganization of the very mode of habitation on our planet constitutes the basis of the development and blossoming of a communist society. Without knowledge of geological laws these ambitious problems cannot be solved, and this alone decides their truly fundamental importance.

Furthermore, in this age of the conquest of outer space, these laws cease to be merely terrestrial ones, for they concern the movement of matter inherent in the general manifestations of all planets. The forthcoming conquest of other planets is turning geology from a narrow "earthly" science to one of cosmic proportions. It will become the basis of comparative planetology, which will inevitably pass beyond the initial, astronomical stage and will then be able to reveal more universal and fundamental laws of true world importance. Even now, geological facts and ideas are beginning to play a great part in unravelling the mysteries of the structure and history of the moon and other planets in the solar system.

Hence the importance of modern geology, or to be more exact, the set of geological sciences into which it has been transformed should not be underrated. It is not only a very important sphere of knowledge from the standpoint of the exploitation of the depths of the earth, but is also one of the major independent branches of theoretical and natural sciences.

It is indeed now that geology is in a position to establish the fundamental laws of the development of the earth through the steady progress made by physics and chemistry as the basis of all natural sciences. Hence, there is no question of stagnation or degradation, but rather of a more tempestuous development and new and important discoveries accompanying it.

REFERENCES

1. Bernal, Dzh., Nauka v istorii obshchestva. [SCIENCE IN THE HISTORY OF SOCIETY]: Izd-vo inost. lit., 1956.

2. Belousov, B. V., O sovremennom sostoyanii teoreticheskoy geologii. [THE PRESENT STATUS OF THEORETICAL GEOLOGY]: Priroda, no. 2, 1953.

3. Kedrov, B. M., O sootnoshenii form dvizheniya materii v prerode. [THE RELATIONSHIP BETWEEN FORMS OF THE MOTION OF MATTER IN NATURE]: Vopr. filosofii, no. 4, 1959.

4. Pospelov, G. L., O kharaktere geologii, kak nauki, i yeye meste v yestestvoznanii. [THE NATURE OF GEOLOGY AS A SCIENCE AND ITS PLACE IN THE NATURAL SCIENCES]: Izv. Akad. Nauk SSSR, ser. geol., no. 11, 1960.

5. Strakhov, N. M., Zhelezorudnyye fatsii i ikh analogi v istorii Zemli. [IRON ORE FACIES AND THEIR ANALOGY IN THE HISTORY OF THE EARTH]: Tr. In-ta geol. nauk, Akad. Nauk SSSR, vyp. 73, 1947.

6. Strakhov, N. M., Izvestkovo-dolomitovyye fatsii v sovremennykh drevnikh vodoyemakh. [LIME-DOLOMITE FACIES IN MODERN AND ANCIENT RESERVOIRS]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 124, 1951.

7. Strakhov, N. M., Osnovy teorii litogeneza. [FUNDAMENTALS OF THE THEORY OF LITHOGENESIS]: T. 1, Izd. Akad. Nauk SSSR, 1960.

Geological Institute of the
Academy of Sciences, U. S. S. R.,
Moscow

Received, 15 June 1961

PETROGRAPHIC RESEARCH ON PROBLEMS OF MAGMATISM IN RELATION TO THE DEEP-SEATED STRUCTURE OF THE EARTH'S CRUST AND THE FORMATION OF COMMERCIAL MINERALS[1,2]

by

G. D. Afanas'yev

The responsible role of science in the ad-ncement of Soviet society toward Communism s given great emphasis at the All-Union Con-rence of Scientific Workers, held in Moscow s year. The Conference, which took place the eve of the XXII Communist Party Con-ess, marked a new stage in the flourishing of ientific research in the U. S. S. R. It showed e high level and success of the determination resolve problems of great national, economic d theoretical importance.

The part played by the earth sciences — geo-gy, petrology, geochemistry and geophysics — our day, during the intensive exploitation of e "storehouses" of the earth's crust, is be-ming a more and more important one. The credible rate of industrial development re-ires the use of ever greater amounts of ectric power and crude ores. At the same ne it is considered that the easily detected posits of ores have been, for the most part, scovered and evaluated. This does not mean, wever, that the "storehouses" in the earth's ust have run out of ores. In actual fact, ience still knows very little of the structure the earth's crust and the laws which govern e formation and distribution of the most luable mineral resources.

In this age of the rapid development of viet science, with its fabulous achievements the conquest of outer space, unravelling of e deepest secrets of the structure of matter, d the development of methods for studying e depths of our planet (geophysics) on the sis of advances in physics and the tracing of e development of certain elements through geological time (radiogeology), we are in a position to venture into the realm of knowledge of the deep-seated structure of the earth's crust and the processes occurring within it and governing the formation of mineral deposits.

But the solution of this cardinal problem in the natural sciences is possible only by the joint efforts of geology, with its extremely valuable historical-perceptional method of investigation, geophysics and geochemistry, with their modern methods.

The origin of fused silicate masses in the earth's crust (magma), the formation of igneous rocks from them and post-magmatic derivatives is an extensive branch of geology-petrography. Petrographers at the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry have put forward the following program for the next few years — "The laws governing the development of magmatism and their importance in understanding the deep structure of the earth's crust and the formation of magmatogenic ores".

The basic trends in this investigation are: (a) study of the connection between magmatism and endogenic mineralization for the purpose of working out a scientific basis for forecasting the occurrence of minerals; (b) the genesis of igneous rocks and laws governing the development of magmatism in the earth's crust in regions with different geotectonic structure; (c) magmatism and the deep structure of the earth's crust on the basis of study of petrographic formations and detailed investigation of matter, including the physical properties of rocks making up magmatic complexes; (d) radio-geological study of rocks with a view to developing an absolute geochronological scale and understanding the specific nature of the material composition of rocks by means of isotopes and other contemporary methods aimed at tracing the inter-relationships between the forming of rocks and derivative post-magmatic processes.

Magmatism and metamorphism are processes

---

[1] O petrograficheskikh issledovaniyakh po prob-ne magmatizma v svyazi s glubinnym stroeniem nnoy kory i obrazovaniem poleznykh iskopaemykh, . 36-56).

[2] Paper read at a session of the Student Council of Institute of the Geology of Ore Deposits, Petro-phy, Mineralogy and Geology of the Academy of ences of the U.S.S.R., 29 March 1961.

of great importance from the point of view of applied geology for understanding the structure of the earth's crust and its development.

Unfortunately, we are not in a position to obtain a complete idea of the nature of geological processes occurring in the depths of the earth's crust. This is due, on the one hand, to the laboriousness and the technical difficulty of experimental research, and on the other hand, to the inadequacy and at times, unsubstantiated, interpretation of the available geophysical data.

In order to confirm our general ideas on the laws for the development of magmatism we require further study of the natural association between igneous rocks — magmatic complexes, formations, and provinces, as well as modern active volcanic systems — which constitute a gigantic laboratory of high-temperature processes.

Two of my articles on the deep-seated structure of the earth's crust have recently been published [11, 14]. This article gives only the more important data on this aspect of the problem.

Since assumptions regarding the composition of the mantle and differences between the earth's crust on land and under the bottom of oceans are often followed prematurely by major geological and petrological deductions, we should stress once again the importance of a very serious approach to the interpretation of geophysical data from the standpoint of geology and petrography.

We still lack enough direct information to make valid judgements with regard to the composition and thickness of the earth's crust and the top of the underlying mantle, despite the fact that the U. S. A. has begun drilling an experimental hole through the bottom of the Pacific off the coast of Guadalupe.

I think it would be more to the point to drill a number of holes on land in areas where the discontinuities inside the crust show appreciable variation in the rate of passage of longitudinal waves. Discontinuities of this kind, which occur at the relatively slight depth of 6 to 7 km, are known in the Ukrainian crystal massif and the Baltic Shield.

Study of the actual geological formation in these velocity zones might explain the difference in the velocity of elastic waves at this and still deeper levels, including the Mohorovičić discontinuity. Of particular interest are the crystalline rocks of the Baltic Shield among which some of the oldest formations in the Soviet Union — up to three billion years old — have been found, and rocks of the eclogitic type, that is to say, drusites developed in the same area with an age close to two billion years. It is important at the same time to stress the fact that the thickness of the crust between this point and the Mohorovičić discontinuity is still 40 km. The crust is still as thick as this in regions of the young folded structures, for example, the Caucasus.

The earth's crust, that is to say the region of active geological endogenic processes, is mosaic in structure and consists mainly of silicate rocks extending to a depth of at least 60 to 70 km (geophysical data for some of the mountain ranges). At this depth, there can hardly be any stratification in a horizontal place of the "granite" or "basalt" layer type, and it cannot exhibit any differences in material composition either in the continental or the ocean regions.

At the same time it should be said without giving into too much detail on the subject, that in view of the primeval heating of the earth during the Early Precambrian, there was probably differentiation of the material into an upper substantially granite layer, and a lower, more basic layer. Later, when the earth was periodically downwarped to the level of the generation of fused material, anatectic magma foci occurred. Two genetic series of igneous rocks are formed in accordance with the magma generation level: they are, first, the series associated with the basic, deeper rocks, and, second, those associated with the higher, gran[illegible] magmas proper. The magmatic differentiation, contamination and crystallization differentiation led to the further formation of a variety of rocks. Consequently, one of the most important problems in petrography, the answer to which is closely linked with understanding of the structure and development of the earth's crust, is the study of the distribution in time and space of natural associations of igneous rocks — complexes and formations.

Without dealing with the petrographic formations and provinces touched on earlier [14], the importance of a detailed study of magmatic formations by all the present-day methods, and the reconstruction of the historical development of magmatism for certain structural-tectonic units on the earth should be taken for granted. Comparative analysis of the results of a study of this kind would supply the necessa[illegible] basis for conclusions on the deep-seated structure of the crust and the ancestral magmas.

In order to understand the structure of the earth's crust and the underlying shell, we mus[illegible] study the associations between igneous and metamorphic rocks most deeply located as regards mode of formation, or the most ancie[illegible] types of the relatively early stage of development of the crust.

Among such series of rocks, petrographers should note in particular the series including t[illegible]

intrusions of ultrabasic and gabbroid rocks and, as is particularly important, thorough study must be made of the metamorphic rocks accompanying them — eclogites, drusites, and other similar rocks.

BASIC RESULTS OF PETROGRAPHIC STUDIES IN THE U. S. S. R.

1. Development of magmatism

In an article written for the XXI Session of the International Geological Congress, I summed up the preliminary results of the study of the evolution of magmatism of a number of folded regions in the U. S. S. R. [13].

The geological history of these regions is complex. The geosynclinal regimes of the state of the earth's crust within the folded regions have been replaced on numerous occasions by platform-state regimes or ones of an intermediate type.

In the case of the regions under consideration (Caucasus, Urals, Transbaikalia and other regions), the following stages in the development of magmatism have been noted:

1) Geosynclinal proper. This is the stage of the formation of the association of basic and acid rocks, principally the sodium type, appearing both in effusive and intrusive facies. The effusive facies develop ophiolitic volcanism — spilites, diabases, and sodium keratophyres. In the intrusive facies this association includes gabbro-amphibolites, ultrabasites, plagiogranodiorites (Tonalites), spassartites, plagiogranites and sodium alaskites. The formation of the intrusive series is completed by small intrusions of sodium syenites and albitites. Data is accumulating, which shows that even as specific a group as alkaline rocks, including nepheline syenites, are geologically associated with the final stage of development of this type of magmatism. The specific concentration of the minerals is associated with this as well.

2) The epigeosynclinal stage of development of magmatism is characterized by downwarping to a lesser depth and formation of magmatic foci within the sialic shell of the earth's crust. This is the stage of the association of the intrusive facies of grano-diorites and granites of basically potassium composition. The more basic members — gabbro-diorites and diorites — are formed through local contamination processes of the granite magma with assimilated rock. The effusive series of this stage is marked by considerable development of the acid effusives (rhyolites and dacites), which are nevertheless quantitatively subordinate to the effusion of andesites and andesite basalts. The periodicity of the renewal of the magmatic complexes, including their metallogenic features, shows the palingenic origin of the corresponding magmatic foci through local anatexis of the sialic shell. The formation of the intrusive series is completed by the introduction of small differentiated intrusions of diorite and granosyenite composition, right down to alkaline rock proper, but of an essentially potassium type.

The development of intrusive magmatism, both the old and the Mesozoic-Cenozoic magmatism, is accompanied by the formation of metasomatic rocks, which are basically sodium (albitized) in the case of geosynclinal, and potassium microclinal in the case of epigeosynclinal complexes.

If existing data on the ages of igneous associations are compared, a striking fact is that the specific series of rocks from different regions are repeated (without being identical) in time, and that those close in age are similar in a number of cases, down to small details.

In particular, the sodium rocks associated with ultrabasite intrusions and accompanied by a specific concenter of ores are usually typical of Caledonian structures for many regions in the U. S. S. R. and also other countries (the Appalachians in the United States).

The batholitic massifs of porphyrite-type granites (the microclines of which are often metasomatic in origin), accompanied by a series of granites and alaskites and in their mineral concenter are typical of the magmatism of the Upper Paleozoic in many folded regions — the Caucasus, Altay, Transbaikalia (Daura complex), Lesser Khingan, and other parts of the U. S. S. R. The studies made by J. Lyons of the geology of New Hampshire and Vermont [28] imply that in this region of the Appalachian system there is an association of rocks, typical of the geosynclinal magmatic complexes proper, including ultrabasites and plagiogranites. Typical microclinal granite intrusions are later occurrences.

As in the North Caucasus, according to Fairbairn, Penson and Harley [27], on the Atlantic coast there are two groups of granites among the New Hampshire and Georgia intrusions which are differentiated on the basis of the absolute age of their micas: one is less than 400 million years old and more than 300 (i. e., Caledonides with an age of about 350 million years) and a second group, whose age is less than 300 but more than 250 million years (i. e., Hercynides, about 275 million years old).

As facts accumulate we observe general laws of a planetary order in the relative synchronous formation of special magmatic complexes with the specific accompanying

mineralization. I made some comments on this point in an article written in 1950 [2].

The repeated association of pyritic deposits with Midpaleozoic (Caledonian) complexes of effusive series and granitoids of the sodium branch, clearly illustrated by the example of the Caledonides in Northern Europe (Norway, the Urals, Northern Caucasus, and the Appalachian system in the U. S. A.) shows that they are more closely connected than by simple territorial contiguity. The young (Mesozoic) complexes of similar petrographic type are also accompanied by pyritic deposits (in particular in Transcaucasia). A peculiar type of carbonate rare-element deposit is associated with ultra-basic and sodium rocks. The mineralization by radioactive elements, which accompanies the Upper Paleozoic magmatic complexes in Central Europe, the Caucasus and Central Asia is also specific. Certain other features of similarity will be discussed below in connection with the problem of the petrographic and metallogenic epochs.

Finally, as I have often pointed out in my published work, examples are known of the development of petrographic single-type rocks of the trachybasalt formation of Tertiary age, assigned to similar geologic structures and close in age, in such distant regions as the Caucasus, Baykal, Egypt and probably the Isles of Skye and Mal (Scotland). The alkaline rock complex of the Mediterranean province (including the leucite rocks) is petrographically identical to the Armenian alkaline complex.

According to Smulikovskiy, the Tertiary lavas of Lower Silesia are represented by basalts, basanites and nephelinites, and according to Bentor, the Cenozoic hypabyssal intrusions of Northern Israel are represented by nepheline-containing rocks.

Examination of the specific features of magmatism and metallogenesis of the Upper Paleozoic and Mesocenozoic in different parts of the world shows the probability of common evolutionary laws in the magmatism of the earth's crust.

2. Granite Formations

V. S. Koptev-Dvornikov and the Kazakhstan group of petrographers has made a correlation summary study of the Paleozoic complexes covering a considerable area of Central Kazakhstan; the material is contained in the collection "Petrography of the U. S. S. R.".

Study of the information obtained by this group of authors has enabled them to publish theoretical generalizations on the features of individual magmatic formations which they have differentiated (see 18 — "Granite formations at shallow depths").

Developing the views of Levinson-Lessing, who, among others, singled out the granite formation, the authors consider it a good idea to divide the formation into two parts: (1) the formation of deep-seated intrusions accompanied by highly-developed granitization, containing virtually no ores; (2) the formation of shallower intrusives accompanied by a variety of deposits; to the latter type of formation the authors assign different-size intrusions to several thousand square kilometers of granitoids) which in Central Kazakhstan, the Soviet Far East, Central Asia and Transbaykalia, solidified, in their opinion, at depths of 0.5 to 2 km.

I consider that this latter, extremely important geological feature of the formation of granite intrusions, when discussing intrusions occupying thousands of square kilometers, requires special proof.

Modern volcanic regions — which are potential areas of intrusive magmatism with subsequent denudation — ought to be composed in this case of contact-altered rocks. Much more feasible at these depths is the formation of sub-volcanic bodies and near-surface stocks of the porphyritic type.

The authors point out a remarkable feature of granite magmatism appearing in different parts of the world: the granite formations are formed by a series of intrusive rocks (granodiorites, granites, leucocratic granites and alaskite) progressively with time. These series were formed in the second tectonomagmatic cycles (for example, the Caledonian or Hercynian) when the geosynclinal sedimentary-volcanogenic formations were replaced by epicontinental and continental red-colored porphyritic formations composed of dacite and rhyolite. This regularity, if somewhat expanded and improved in accuracy, can be applied to magmatic processes in most of the mobile belts. The authors do not deal with intrusive magmatism inherent in geosynclinal downwarping and represented by ultrabasites, gabbroids and granitoids mainly of the sodium branch. Spatial coincidence with a porphyritic formation, speaking simply, with an effusive facies of the same granite magma, is hardly possible for intrusives making up large areas.

The authors raise interesting problems on the emplacement of the granite magma — a problem of space. They solve it by assuming complex interaction between tectonic processes and magma energy. The granite process of formations of shallow depths splits up into three phases — the vein rock phase constituting two stages.

I expressed my own view regarding the problem of lamprophyric vein rocks in a separate publication [8]. It seems to me that there the

relationships between the comagmatic basic vein rocks with granite intrusions and the rocks of the later stage of the granite process — leucocratic and alaskite granites — have not been adequately explained. Data recently obtained on the absolute age of granites and the enclosed basic vein rocks confirm my earlier conclusions [8]. A very important fact which truly helps to solve petrographic problems and gives a clue to the connection between ore mineralization and granite magma is the study, stressed by our colleagues, of minerals of the intrusive, vein and contact of element admixtures.

Study of the granite intrusions of Primor'ye, Transbaykalia, Kazakhstan, Central Asia, and even in the Caucasus and other areas, shows that the enrichment by certain ore elements and minerals, as compared to the Clarke constants, and also the presence of concentrations from time to time in them of accessory minerals, shows quite clearly that with favorable structural conditions there can be a spatial link between intrusions of commercially important quantities of ores.

A great deal of material on the distribution of a number of admixed elements — tin, lithium, zinc, lead, and zirconium, etc., in rocks of different stages of granite complexes and of different ages, together with a comparison of the data with specific ore formations shows both the value and need for petrographic-geochemical study of igneous rocks, as often stressed by Levinson-Lessing, and particulary by Lebedev.

In view of the publication of the basic results of study in this field by one of our large groups I must disagree with the categorical rejection by the authors of the old so-called Rosenbush sequence of crystallization of minerals. It cannot be considered that the earlier crystallization of potassium-sodium feldspar and quartz, compared with biotite, is a phenomenon typical of granite rock (of magmatic origin). Such an interpretation of the sequence in mineral formation during the granite process would require an explanation of the irreversible relationship clearly observed under the microscope between these minerals and certain data on the fusability and crystallization point of different minerals, in particular, those discovered by the experimental research of Wyart and Sabatier [31].

3. Formations of Basic Rocks

In the field of study of the regularity of the development of formations of basic rocks predominantly in platform regions, some of the results obtained by a group headed by A. P. Lebedev were described in an article he wrote for the XXI Session of the International Geological Congress, entitled "Features of Magmatic Processes and Mineralization Under Platform and Ancient Shield Conditions". Lebedev draws attention to the fact that the magmatism of the platform and oceanic depressions have similar features: in both cases there is a sharp predominance of basalt magma derivative rocks, the source of which is the sima. The differences are due to a considerable extent, according to Lebedev, to the different levels at which the sima lies. At the base of the platform there is usually an ancient granite-gneiss foundation with a basement of crystalline and metamorphic schists. The basic magmas of the Mesozoic and partially of Tertiary age (Deccan, India) form fissure-like intrusions in the rocks of the basement and sills, and sheet intrusions of dolerites, diabases and gabbroids (traps formation, as they are called) in the upper cover of sedimentary, slightly dislocated rocks. All of this shows the small role played by sialic matter in the upper (granitic) region of the earth's crust for geological ages, during which this segment of the globe was a platform. This does not preclude the occurrence of small masses of acid differentiates in isolated stages of the formation of the trap magmatism of the platform.

Lebedev is inclined to link the more acid tholeiitic magma in the ancient shields with deep contamination of basalt magma of the sial, giving rise to the geochemical differences in the mineralization associated with the platform magmatism.

The magmatic type of mineralization associated with platform magmatism — titano-magnetite and copper-nickel mineralization — were determined, according to Lebedev, by the specific nature of the deep magma which underwent differentiation at the intrusion points. Post-magmatic mineralization — magno-magnetite deposits — Iceland spar — is due to the specific nature of magma in the mode of its crystallization in the upper structural stage.

4. Formations of Alkaline Rocks

Although alkaline rocks are a highly specific and far less common type of rock, their features in common with magmatism as an endogenic process, a legitimate part in which is constituted by the development of alkaline and sub-alkaline magmas and rocks, are being revealed more and more clearly.

Alkaline rocks, differ in composition and association with other igneous rocks, and are related to formations having an extensive age range and occur under different geotectonic conditions (platforms, mobile belts, young folded structures).

Accumulated data show that alkaline

magmatism is probably a natural link in the chain of magmatic processes forming a material representation of tectonic-magmatic cycles in the development of the earth's crust.

In his report given at the XXI Session of the International Geological Congress, O. A. Vorob'yev gives a short description of the most important regions of development of alkaline magmatism. As can be seen from the information he presents, alkaline magmatism is frequently found within a particular territory, — the Urals, the Kola Peninsula, and many other regions.

On the Kola Peninsula, remnants of picrites to the phonolites of porphyrites are retained in the top of the Devonian, and at the same time the intrusions of the central type of iolite-melteigite series associated with ultra-basic rocks aged 375 to 340 million years, i. e., Devonian on the 1960 scale. The nepheline syenites from the final stage of alkaline magmatism have intruded to the boundary of the Carboniferous-Permian (260 to 280 million years). This association of volcanites and plutonites in time in the case of a single structure is also noted for alkaline magmatism of the Devonian and Tertiary period in the Caucasus (Armenia and the North Caucasus).

Just as important is the closeness in time observed between the development of these specific igneous formations for distant and tectonically differing regions. An illustration of this is the different scales of alkaline magmatism of the Devonian period on the Kola Peninsula (picrites, phonolites in the effusive facies, and iolite-melteigites in the intrusive facies) and apparently, the Devonian of the Northern Caucasus with its pyroxene sub-alkaline and alkaline porphyrites of the Lower Devonian and granosyenites of the top of the Middle Devonian (absolute age 340 and 325 million years).

The alkaline rocks of the Pacific belt — Maritime region and Sakhalin have not been adequately studied from the point of view of age, but inasmuch as they are Mesozoic-Cenozoic, they are to some extent the same age as the alkaline magmatism of the Caucasus (nepheline syenites of Armenia, teschenite-syenite formations in Georgia and sub-alkaline gabbroids and trachites in the North Caucasus, including the titaniferous-augite gabbroids of the Chaokha massif). Consequently, the specific manifestations of magmatism are close in time for such distant structures as the Pacific belt and the Mediterranean zone. In his report, Vorob'yev stressed the idea of two genetic series of igneous rocks from the alkaline magma.

1. Associations of alkaline rocks of predominantly platform type showing the common origin with the preceding ultra-basic intrusions.

2. Associations of alkaline rocks which developed as the alkalinity progressively increased during the evolution of the granite foci in tectonically active zones (folded areas).

The geosynclinal series of igneous rocks of different ages, as shown by the example of certain areas, were undoubtedly completed by the associations of alkaline rocks and the alkaline metasomatosis processes connected with them. In their chemical affinity and geochemical characteristics, however, these associations seem not to be identical, because of the downwarping depth of the geosynclines.

In this respect we need to study the formations of the alkaline rocks associated (1) with the geosynclinal series proper, including ultrabasites and granitoids essentially of the sodium type and (2) with the granitoid series essentially of the potassium type formed in structures which seem to have undergone less deep downwarping.

Under platform and naturally more stable conditions, the magmas at the deeper levels of the earth's crust (at the level where melts are generated) are probably primarily ultra-basic or perhaps basaltoid, have the needed energy reserves and penetrate the upper layers of the crust under favorable tectonic conditions. Primarily alkali-rich magma could hardly become contaminated by intruding the sialic shell, even during protracted movement to the upper structural stages, or could hardly become differentiated at the site of the intrusion, thereby forming rocks ranging from ultra-basic to nepheline syenites.

The platform associations of alkaline rocks, in the generation of which alkali-earth rocks of the sialic crust undoubtedly play a minor part (since they are not moved by downwarping to the remelting levels — anatexis), differ from the alkaline formations of the folded regions in the scale of the intermediate granitoid members. By dint of the activity and mobility natural to alkaline differentiates of the platform as well as geosynclinal magmatic series, they are carriers in a number of cases and also ore generators, particularly rare elements.

It is a very difficult problem for petrographers to ascertain the specific composition and metallogenic features of alkaline magmas of different ages, genetically associated with ultrabasic — basaltoid or granite magmas under different geostructural conditions.

We should also stress the importance of studying the alkaline formations in understanding the deep structure of the earth's crust. Examples of ultra-basic effusives associated

h alkaline-type rocks of Devonian age on the a Peninsula or the alkaline formations of ıtanga (Siberian platform), now known, sugt that the associations of oceanic rocks were med in segments of the earth's crust which e now become continents.

5. Magmatism and Mineralization

An important problem here is the magmatic non-magmatic origin of granitoid rocks the ater part of the deep igneous outcrops on earth's surface at the present time.

The problem of granites was discussed at a nposium held in Moscow in 1961 on the prob1 of magma and the genesis of igneous rocks.

In the light of data contained in my report he symposium on the synchronization of usive and effusive manifestations of Upper eozoic, Upper Mesozoic and Tertiary granite gmatism and on the geochemically specific tures of granitoids and their relationship h the enclosing rocks accompanied by data absolute age, the feasibility of granite mag and active interaction with the enclosing k is clear.

Ustiyev's conclusions and also those of dington on plutonic-vulcanic associations more or less the same [24, 26].

At the same time, we should point out that recognizing the pre-eminence of magma in formation of granites, we should neverthes regard a large group of granitoid rocks as erogeneous formations.

Two types of magmatic granites proper e been pointed out: 1) active, relatively h-temperature types with corresponding nposition and structure of contact neoeses; in this group the mineral phase ratios almost anchieutectic; 2) relatively low perature granites of an alaskite composition h related quartz, orthoclose and plagioclase ios, are almost anchieutectic.

Furthermore, the latter group is usually ociated time-wise with porphyritic, or her porphyroblastic, granitoids of metanatic origin, for which the points of their ırtz-feldspar composition fall outside the tom range on the Tuttle-Bowen triangular gram, of the characteristic anchieutectic ios of these components.

Geochemical study of the granites and cont rocks shows that the formation of granites not accompanied by a loss in mineral compots, such as the radioactive elements, which ght have been expected when granite rocks re formed during ultra-metamorphism. ere is hardly any point at the present time in speaking of one single method of granite formation. The formation of granites is a heterogeneous process, but the metasomatic granites and metasomatized gneisses are a second-order phenomenon caused by the evolution of magmatic foci, the magma in which it is able to generate differentiates of the granite proper and of lower-temperature alaskite composition.

Turning to general problems of metallogenesis as the point of departure in forecasting deposits, it should be pointed out that the general principles of the link between endogenic mineralization and active magmatism used as a basis for elaborating the hydrothermal theory of mineralization has been frequently criticized from various points of view. Problems of the genetic connection between the mineralization and specific granite intrusions have been more of a subject of controversy than any other branch of teaching on the ore deposits, even for magmatic specialists.

If the genetic relationship between contact metasomatic (skarns) and many high-temperature hydrothermal ore formations and intrusions is considered proved by magmatic specialists, the link between hydrothermal deposits of the lead-zinc or mercury-antimony type with certain intrusive cycles or their stages is usually difficult to ascertain.

In considering conditions for endogenic mineralization in the Precambrian, N. G. Sudovikov touches on the general problem of the connection between endogenetic mineralization and granite [23]. He feels that the idea of a direct link between the deposits and granite intrusions has been shaken recently by new studies showing the only slight mineralizing ability or granite magma.

According to Sudovikov, this stems from the now-known fact that granite magma may contain, in accordance with the mode of formation, a very limited number of volatile components and is produced by a substratum which before being converted into magma experiences changes leading to the separation of many ore components. This generalization of absolutely all manifestations of granite magmatism is repudiated by numerous facts on intrusions with which the ore deposits are definitely either genetically or paragenetically related.

Experiments carried out by Goranson and Khitarov show that in the granite melt (and basalt, too, according to Khitarov), at 900° and 3000 kg/cm^2 steam pressure, the water content is more than 6% (Khitarov) and about 3% in the basalts. This indicates a possibility that hydrotherms can separate out during crystallization of the granite magma.

With regard to hydrothermal mineralization, Sudovikov thinks that a definite part in the

migration of ores is played by processes of consecutive regional metamorphism and ultrametamorphism.

Mineralization is characterized by three processes: mobilization of the ore matter, its transfer and deposition. He regards mobilization from a general standpoint, quoting granitization specifically as an example (as an indicative example! ! !). The transition from biotite shales and gneisses to leucocratic granitoids is accompanied, in Sudovikov's view, both by the separation of iron and magnesium (biotite decay) and by the disappearance of a large number of elements making up the biotite in small quantities and not restrained by the quartz lattice or feldspar lattice.

It should be said in this connection that as an illustration Sudovikov takes an extremely limited number of granites formed during alkaline metasomatosis, and does not mention granites formed magmatically. Furthermore, the behavior of some elements, for example uranium, often conflicts with his statement. To support his line of argument, Sudovikov quotes data from L. V. Tausen and L. A. Kravchenko on the distribution of zinc in quartz and in feldspar, on one hand, and in biotite granitoids, on the other, purporting to show that in certain cases biotite contains ten times more zinc than quartz or feldspar; the same thing applies to titanium and tin.

Sudovikov apparently considers this biotite to be related to the relict systems, rather than granite, which should be proved first; furthermore, there is need for proof that these elements were lost during the transformation of schist into granite, i. e., it should have been shown that the biotite in the crystalline schists contains these elements, and that the granite biotite does not. But, first of all, we must find out whether the crystalline schists themselves are the result of the processing of the roof by active granite derivatives; that is to say, to solve these problems, too, we must examine specific material and prove that the granites were produced by low temperature quartz-feldspar granitization, while the biotites in the crystalline schists were formed through regional metamorphism and contain all the elements, and in large quantities, to boot, which are present as well in the granite biotites. At the present time there is a lot of information supported by radiological studies showing that the mica (Bi) in contact aureoles is formed during intrusion of the granite magma, and not through the preceding metamorphism. According to Sudovikov, the transfer usually involves great difficulty. The mode of transfer, distance, mode of migration and reason for the transfer are still unexplained.

He writes that ore deposition is usually explained in terms of the ore-forming role played by granites. Since it has now been proved, he says, that the granites in this spect are "not guilty", he thinks that the pr lem of ore deposition should be reapprais

From this position, (metamorphism an mobilization) he explains all of the princip of hydrothermal ore formation which have based so far on facts showing the connectio between the hydrotherms and active granite trusions.

In the work of our petrographers on the problem of the development of scientific ba for forecasting the occurrence of commerc minerals, the ideas of Levinson-Lessing, Zavaritskiy and Smirnov on the genetic rela tionship between magmatic and ore-generat processes, are a basic foundation.

At the first All-Union Petrographic Conf ence held in 1953, I drew attention to some portant ideas advanced by Smirnov [21, 22] the study of the magmatism of specific ore regions and on the hypothesis of the evoluti of magmatic mineralization in terms of tim I will deal briefly here with some of the poi stemming from specific studies by our petr graphers and also with some examples of foreign investigations on corresponding pro lems.

A paper by F. Turneaure [29] develops question of the relationship of metallogenes age, igneous rocks and tectonic structures. regards the distribution of different ore for tions in structurally different regions — sh and mobile folded belts.

As an example, I shall discuss his data the Appalachian system, since the magmati and metallogenesis of the Appalachian belt similar in overall features to the magmatis the North Caucasus.

Within the mobile belt — of the Appalach system (from Newfoundland to Alabama), h distinguishes three orogenic periods: (1) Taconic-Late Ordovician; (2) Acadian-Late Devonian; (3) Appalachian-Late Carbonifer Deformations of other ages have local signi cance. The main intrusive activity, with manifestation of large granite intrusions, i associated with Acadian orogeny in the nort part and with Upper Carboniferous (Appala in the southern part. The ultrabasic intrus in the Appalachian belt are developed from Georgia to Newfoundland. They are consid to be Late Ordovician or Late Devonian.

The northern part of the Appalachian be with the development of Acadian (Late Devo folds includes sulphide deposits (particular in Southeast Quebec). Lenses and irregula bodies of copper and iron sulphides are im in the metamorphozed sedimentary rocks a

sives. The ore formed later than the meta-phism, which is associated with the New ıpshire magmatic series of Post Lower De-an age.

.ll of these features enable us to compare pyritic deposits of the Northern Caucasus ıp and Beskes) with the sulphide deposits ıe Appalachian system. The normal Car-ferous granites are associated with the ırrence of gold, tungsten and copper (North olina). The lead-zinc province of the hern Appalachians is similar to the Sadon ıp of polymetallic deposits. In the western ntain systems forming the Pacific belt we nevadite (Late Jurassic — Early Creta-ıs) and Laramie (Late Cretaceous — Early iary age) orogeny.

'he resemblance between the magmatism metallogenesis of different ages in the ile belts of North America and those of the esponding ages in the development of the ile belts in the U. S. S. R. stands out even ı a sketchy analysis of the metallogenesis ıe system.

'he theoretical views held by Turneaure be reduced to the recognition of the associ-ı between ore deposits and igneous rocks. sulphide deposits (copper and iron) are ciated with basic and ultra-basic rocks, he lead-zinc deposits are associated with rocks, including the known connection the rhyolites in the silver-tin mines of via; generally speaking, Turneaure does go into detail on the question of associ-ıs. In his specialized, but brief review of relationship between mineralization and itization, he takes into account views ex-sed by Sullivan, Baklund and Magnusson, gives no definite opinions himself.

ı a brief section on metallogenic epochs, onsiders the views of Schneiderson to be ulative. As a whole, Turneaure is in-ed to combine the ages of "metallization" major events in the history of the earth. ırticular, he considers that the Laramie allogenic epoch occurred in different re-s during the Tertiary period.

'rom the example of this article we can that his general metallogenic developments not gone beyond the bounds of a prelimin-interpretation of the most widely known s.

.n unusual approach to explaining the rela-ship between the copper-zinc mineralization minor granitoid intrusions of complex position is taken by C. Banks Belt [25] in study of a number of features in New ico. I will not describe this study in de-but will merely say that in the contact ole of the Hanover, Magdalena and Lordsbrug intrusions studied by him there are deposits of copper and zinc. The Tertiary intrusions were not formed deeper than 3. 5 km. In order to ascertain their relationship with mineralization he considers geological maps of intrusives with all vein and enclosing rocks. Then, solely for areas occupied by granitoids proper, on the basis of systematic sampling he produces maps showing isolines of equal orthoclase-plagioclase ratios, the distribution of plutonium, copper and zinc in the samples, and the degree of alteration of the rocks. When these maps are superimposed, the maxima of individual processes do not coincide. The authors are forced to leave the solution of the problem of the removal of zinc and copper to the enclosing rocks from intruded montonites and tonalites until other features, more favorable for a solution, have been investigated. Although he studies the granitoids of the plutons having an area up to 2 or 3 km^2, Banks Belt does not touch on other rocks associated with the intrusion — lamprophyric dikes, rhyolite dikes, etc. Nor has he studied small bodies of diorites in the western part of the Hanover pluton, although the copper concentration in the samples is clearly maximum in the granitoid intrusions, just in this marginal area.

In studying the complex association of rocks he uses basically the formally statistical method of studying the distribution of different compositions in pluton granitoids proper, without special study of the geochemistry of the pluton in the light of its evolution with the development of different stages of the intrusive massifs. In particular, the dikes do not seem to be of interest to the author, and his aim is merely to explain the possibility of ore generation by the granites themselves. Obviously, without study of the preceding diorites and subsequent vein granodiorites and lamprophyres the statistical distribution of copper and zinc content gives an unintelligible picture of the genetic relationship between mineralization and the frequent manifestations of the granite process which have formed the intrusive complexes of New Mexico.

The great amount of both our own and foreign literature on the genetic relationship between magmatism and mineralization suggests that the views of this problem are basic ones in the present day teaching on the genesis of ore deposits and petrology. This cannot be proved, however, for all types of ore formation with adequate conviction.

Ore deposits of the Mercury of even the veined lead-zine type are usually located some distance from the generating magmatic sources, and the general geological environs and geochemical study alone enable us to put forward any convincing arguments.

The example of the North Caucasus

emphasizes the genetic relationship between mercury mineralization and the Cretaceous magmatic complex of sub-alkaline rocks [15].

With regard to a large number of copper-pyrite deposits, most geologists agree with the genetic relationship between this type of mineralization and magmatism, although they differ in their approach to it. Some consider them as deposits genetically or paragenetically associated with sub-intrusive formations, while others stand by the volcanogenic-exhalation hypothesis.

Of late a great deal of convincing information has been produced with regard to the genetic relationships between ore deposits and specific granite intrusions. It should not be forgotten here that in most cases what we actually call an intrusion is only a small area uncovered by denudation, of a large granite mass reaching to a considerable depth.

Criteria determining the presence of genetic (and partially paragenetic) relationships between specific magmatic rocks and ore deposits, as formulated by me in 1950 [3], may be based on (1) structural-territorial contiguity of magmatic and ore complexes; (2) the proximity of age and degree of metamorphism of magmatic rocks and ore complexes associated with them territorially; (3) the specific nature of the composition of magmatic rocks (accessory minerals and elements) similar to that of ore formations and vice versa; (4) certain relationships between different types of mineralization and igneous rocks (keeping in mind the mode of occurrence and distance from the intrusions).

Using the Voznesensk granites as an example, M. G. Rub has shown the genetic relationship between them and tin and rare element deposits. In her studies of this subject she gives particularly convincing geochemical data showing the accumulation of specific elements in the rock-forming minerals in the granites; for example, tin in the biotites. The same thing applies to the commonplace nature of such elements as rubidium, lithium, beryllium, thorium, etc. In her geochemical study of parent rock, she has come to interesting conclusions showing that the predominant amount of elements with a "mining" importance were introduced in the enclosing rock by active intrusions. In turn, the magma reacted with the enclosing rock, borrowing from it small quantities of elements alien to the normal granite magma — vanadium, chromium, cobalt and perhaps copper.

The direct connection between tin deposits of the quartz-cassiterite formation and the Upper Cretaceous Mar'yan granites, apart from other data, is fairly convincingly shown by the development of cassiterite in the miarolitic cavities in the granites.

Favorskaya and Rub, selecting the subvolcanic intrusions of the Far East as an example, link them genetically to the polymeta (Tetyukhe) cassiterite-sulphide and quartz-cassiterite mineralization, substantiating thei view with geological, petrographic and geochemical data.

In many reports given at two All-Union Petrographic Conferences (1955 and 1960) the is indication of the genetic link between mineralization and magmatism illustrated by specific examples.

The genetic relationship between chromiur and platinum deposits, on the one hand, and ultra-basic rocks on the other is well known and completely accepted. A number of rare earth elements are genetically related to gran magma derivatives, and a still greater variet of rare element concentrations is typical of alkaline complexes.

The sum total of the natural phenomena studied suggests a genetic or paragenetic rela tionship between mineralization and magmatis and in many cases that can be proved. But th criteria described above are still insufficient for forecasting the occurrence of endogenic minerals, since they only confirm the relatior ship between known deposits and intrusions already discovered, although this is also important inasmuch as it may have a favorable effect on the prospects of developing the given region. We know of an interminable number intrusive bodies of varied petrographic compo sition, with which ore deposits are not associ ated. The task facing petrographers, therefore, is made more difficult since it requires elaboration of petrographic criteria for prospecting hidden deposits.

If we take the point of view that the known ore-bearing nature of certain intrusions is du to the so-called specialization of magmas, thi means, basically speaking, rejecting the connection between mineralization and magmatisr This stems from the fact that by rejecting ore contamination at the site of intrusions, with which many petrographers agree, we transfer the cause of "specialization", that is to say th ore-bearing nature of the intrusions, to the ur known depths of depth of occurrence of anatec magma foci, taking for granted that there is c contamination of the granite magma by the en closing rock, but that it occurs at deeper leve of the earth's crust.

This postulate, which is easy to accept, is not satisfactory to us since the empirically di covered stanniferousness of many regions of t Soviet East provides no clue to an understandi of the absence of tin deposits in the Urals, Altay, Central Asia and the Caucasus.

A very possible reason may be that the

-bearing nature of granite magma of a def-
e geostructural unit in the earth's crust is
extensive; but it is not out of the question
t the potentially ore-bearing magmas were
alized in less favorable conditions or dif-
ed from each other in specific features of
nposition which did not favor concentration
the separation of particular ore components.
s possible that during the crystallization of
magma and its derivatives there are
uliar catalysts at work, so far undetected.
s quite natural that a certain part is played
the environs of the site of the intrusion.

Studies made by many of our petrographers
w the empirical nature of the content of
essory minerals and accessory elements
gneous rocks in magmatic complexes with
ich mineralization is genetically associated.
V. Rabinovich, considers, on the contrary,
t the ore-bearing magmatic complexes do
contain an increased amount of the ele-
nts forming ore deposits (papers of Second
rographic Conference, 1960).

This means that for the moment we should
make the relationships between minerali-
ion and magmatism, discovered for a single
ion, or the justification for them, a general
ncipal.

I would like to make some very general
nments regarding the empirically dis-
ered laws governing endogenic deposits in
ir genetic relationship to certain stages of
gmatic development. First of all, as is
plied by what has been said above, the de-
opment of magmatism in geosynclinal re-
ns results in the formation of two different
es of magmatic series: (a) a series forming
ra-basic rocks, gabbroid, paleogranodiorites,
giogranites and potassium-sodium alaskites
sically sodium), and pegmatites. Under
orable structural conditions, development of
se series is completed by alkaline formation;
a series forming batholitic intrusions of
anodiorites, granites, alaskites, excluding
ultra-basic and gabbroid members of the
ies, but also completed under favorable
uctural conditions by the intrusion of
aline complexes differing from alkaline rocks
the previous type.

The origin of the foci of the primeval mag-
s for these types of series takes place at dif-
ent levels of the downwarping of the earth's
ıst.

The relegation of sources of the two types to
ferent downwarping levels is logical from the
nt of view of the idea entertained by many
entists of the primary differentiation of
tter into shells having different compositions.
re the problem of ancestral magmas is
sely linked with the deep structure of the
rth's crust.

For the moment we do not know the true thicknesses of the shells on the surface of our planet, but they can hardly be reckoned in single kilometers. They are more likely tens of kilometers thick.

The different types of magmatic series are associated as well with different types of ore deposits, but differently aged, though single-type series naturally have specific features. For example, pyritic ores associated with the sub-intrusive bodies of the Caledonian series are encountered in many corresponding structures of this age all over the earth. At the same time, the pyritic ores associated with the magmatic series of this type, but Mesozoic, also have their own features. I mean by this the pyrites of the Caledonides in the North Caucasus and the Allaverdi Mesozoic pyrites.

Hercynian intrusions of magmatic granites proper (non-microclinized) are accompanied by rather small, through appreciable, deposits of tungsten, tin, radioactive (basically uranium!) and rare-earth elements (often the yttrium group). This specific mineralization is found naturally in the Hercynides of Siberia, the Caucasus, Europe and North America (Appalachian system). The strong Mesozoic-Cenozoic magmatism of the eastern region of Asia has produced very important deposits of tin.

V. L. Barsukov [16] considers that the granite massifs which have no tin mineralization contain 3 to 5 g/t tin, which corresponds to the normal amount in Clark units. The mineral concentrate for tin is biotite. In stanniferous granites, the tin content in the biotite ranges from 80 to 100 g/t to 300 to 400 g/t, but does not exceed 30 to 50 g/t in the non-stanniferous granites. I should say, however, that this may be true as regards the potential ore content, but if we compare the tin-bearing granitoids of the Amur region with the Mesozoic-Cenozoic granitoids of the Northern Caucasus, for the moment "non-stanniferous", we see that their geochemistry is similar. There is reason to believe that the Cretaceous granitoids in many regions are potentially ore-bearing in nature, but that the deposits have not yet been found, or that, apart from potential ore-content, other conditions are needed to form the deposits.

Keeping to these very general data, I would like to stress that magmatism and the associated orogenesis are an indication of endogenic processes inside the earth's crust, and, like any geological phenomenon, these processes have a development, and therefore a history, with specific stages. This gave rise to the motion of petrographic and metallogenic ages which I expressed a long time ago, in agreement with D. V Tirrel, V. A. Obruchev, and to some extent, S. S. Smirnov. This idea cannot be disregarded in working out a scientific basis for forecasting minerals.

The geochemical study of intrusions, their contacts and the derivative intrusions of different ages, shapes, degree of denudation and facies will definitely help to find petrographic criteria for the forecasts. The study should be aimed at working out a program both for intrusions associated with ore deposits and for intrusions which for the moment are not associated with them.

I should say that the latter depends to a tremendous extent on the extent to which the territory has been studied. It must be remembered that the oreless Caucasus, which has been studied for more than 100 years, has revealed only the secrets of the Tyrna-Auz, Urup and Kyzyl Kol in the course of the last 25 years. It should be said, for example, that it is only over the past year that geologists have discovered mercury deposits on the western edge of the Northern Caucasus.

I feel that the view that all the ore outcrops have been discovered is not borne out by practice, even in the case of such seemingly thoroughly studied regions as the Caucasus. What about the mountain systems of Siberia, its forest and tundra? We require a great deal of effort, new contemporary methods, a good geological basis and sound ideas, which as far as possible have already been tried out. It is only then that we shall be able to provide all the minerals required by the national economy at a faster rate and with less manpower, money and time.

SPECIAL RESEARCH REQUIRED IN DEALING WITH PROBLEM OF MAGMATISM

A purely geological approach to magmatism, which is absolutely essential, must be accompanied by a detailed study of the composition of rocks and associated deposits.

During the present stage of rapid development in the exact sciences and in engineering, for geology as a whole, and for magmatism and orogenesis in particular, the incorporation of certain modern methods of studying matter in its historical light in the activity of petrographers is extremely important. By this is meant radiogeology, geophysics and exact X-ray-optical studies. Particular attention should be given to experimental research under conditions of varying temperatures and pressures using volatile matter.

In order to avoid misunderstandings, I consider that an obligatory condition for success in using the new methods in petrology is their application to materials and features alone, requiring to be studied in a geological-petrographical respect. In short, a firm geological basis must be created for study of any feature, for it is only then that investigation, for example in the field of radiogeology including studie[s] of the abundance of, first and foremost, po[tas]sium, argon, uranium, lead, and strontiu[m iso]topes, will be of any value.

In particular isotopic investigation to dis[-] cover the location and ratio of these isotope[s in] the mineral phases, enables us to trace the [de]velopment of minerals (their genesis and al[tera]tion with time), thus forming a basis for und[er]standing the genesis of rocks and associated ores, and geological modification over a lo[ng] period of time.

Radiogeologic studies cannot be detached from the history of the development of the r[ock] to which it is applied.

Apart from laboratory study of absolute a[ge] we must develop methodological research to [in]crease the sensitivity and accuracy of meth[ods.] Then we shall be able to learn the sequence [of] the development of processes in rocks with greater certainty, and this will help us to un[der]stand contact processes, metasomatism, an[d] the time and place of the emission of volatil[es] and ore components; it will also enable us to gain a better idea of the development of rock[s as] a whole. Three methods can be used for thi[s] purpose: the potassium-argon, uranium-lea[d] and rubidium-strontium methods. Discover[ing] the age position of igneous rocks and associ[ated] ores is essential for a correct understandin[g] of the development and relationship of rocks and deposits, that is to say, it is one of the fundamentals for scientific forecasting.

It is very important to combine study of the evolution of isotopes of minerals with detailed, optical-X-ray structural study of biotites and feldspars so as to explain the structural and material changes in rock-forming minerals. There is a great deal of study of [a] prospecting nature to be done.

In recent time we have been able to accu[mu]late more and more data on structural modif[i]cations of minerals. This applies to the so-called "ordering" of the crystal structure in many of them. A good example of different degrees of "ordering" are sanidines and mic[ro]clines.

Whether or not the process occurs in tim[e] from the disordered to the ordered state or whether under certain conditions the minera[ls] may crystallize as ordered modifications, w[hile] in other conditions they crystallize as "disordered" modifications are problems which, when solved, will enable us to study genetic petrology more confidently.

There is no doubt that all the transformations in the crystal lattice of a mineral whic[h] show up in the optical and chemical composition, and in the variations in the planar dist[-]

ive geological events, and an understanding em by means of isotopic or optical and ay-structural analysis will bring us much er the solution of general petrological lems. It is vital for scientific research tutions engaged in the study of the earth's t and the rocks composing it to study the ical properties of rocks and rock-forming erals, including the magnetic state, elec- al conductivity and elastic properties.

Without a systematic study of these constant es, no interpretation of data from geophysi- studies will be as valid or thorough as it ld be at present, or as it should be in view e great amount of money being spent on hysical research. A great deal of publi- has been given to the program in this field study of the depths of the earth's crust, in icular, the organization of experimental arch on the elastic properties of different s, including the densest variety of eclogites. l merely add that it is advisable to expand GEM research projects, since stone mate- can be studied at the Institute from all ts of view.

igh-speed and micro-methods of determin- he majority of elements with the required racy, including the ones disseminated in emely small quantities, may reveal geo- nical traces enabling us to make deductions rding the development of magmatic proc- s and associated mineralization, as well ne genesis of igneous and metamorphous s.

mong these investigations is a more ough understanding of accessory minerals, articular, methods of separating them.

The ever increasing importance of new geo- ical methods at times gives some scientists son to think that present-day petrology can dvanced only by experiments on and study atural rocks in the laboratory. I think all experimental possibilities are still limited, pared to the variety and duration of proc- s which have occurred and are occurring ne tremendous laboratory of the earth's st, that observation of events in nature on spot should not only be not discontinued, expanded in every way and that the investi- r should be given full opportunity for an ctive examination of the phenomena.

n addition to the development of research g these lines, at the present time we must at something which so far petrographers e not bothered about — the discovery of new s of crude minerals. Rocks usually contain rge number of valuable elements in dis- inated form. In a number of cases the rocks heir variation products (weathering crust, vial deposits, loose tuff) are already the subject of study and processing for industrial purposes.

In view of the increasing amount of raw material required for the national economy, it seems to me that it is essential to outline prospects for the use of derivative ultra-basic rocks (list varieties, etc.) as possible sources of nickel, chromium and other elements. This approach to rocks as the ore of the future applies in particular to the alkaline complexes and certain derivative granite magmas and effusions which, given the new technological methods, will most likely be profitable sources of beryllium, lithium and other rare elements. The same thing can be said of titanium, niobium, tantalum and, last but not least, radioactive minerals as potential material for power engineering in the future. Our task is to bring to light as soon as possible, even if only the empirical laws governing the accumulation of increased concentrations in different rocks of such vital elements as uranium, thorium, lithium, beryllium, tantalum, titanium, the rare earths and certain others on the basis of composite study of magmatism.

In conclusion I should stress that if petrographers are to solve the problems facing them successfully, they must:

1. Develop and step-up in every way isotope research (on potassium, argon, uranium, lead, thorium, rubidium and strontium) required for (a) shedding light on the sequence of all-geological petrogenic and metallogenic processes; (b) using the elements as tracers for discovering migration during metallogenesis associated with different processes.

2. Carry out extensive optical and X-ray-optical studies so as to understand better the laws governing composition and properties for diagnostic purposes and also to study structural changes as functions of mode of formation, metamorphism and period of existence of minerals.

3. Organize the study of physical properties of rocks — their magnetic receptivity, residual magnetism for series of different ages. There should also be greater study of elastic properties of rocks under different temperatures and pressures, under water saturation and for rocks of different composition and structure.

4. Give attention to systematizing and classifying rocks. At times we do not see the forest for the trees; sometimes different rocks are given the same name, or conversely, genetically similar rocks are given different names, as often happens, for example, when describing diabases, lamprophyres and granitoids.

All of these studies should be based on detailed field study of natural associations of rocks (formation complexes, etc.) coupled with full knowledge of the composition of the rocks.

REFERENCES

1. Afanas'yev, G. D., Opyt sopostavleniya intruzivnykh kompleksov nekotorykh oblastey SSSR. [AN EXPERIMENT IN COMPARING THE INTRUSIVE COMPLEXES OF CERTAIN AREAS OF THE USSR]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1949.

2. Afanas'yev, G. D., Granitoidy drevnykh intruzivnykh kompleksov Severo-Zapadnogo Kavkaza. [THE GRANITOIDS OF THE ANCIENT INTRUSIVE COMPLEXES OF NORTHWESTERN KAZAKHSTAN]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 69, petrograf. ser. (no. 38). 1950.

3. Afanas'yev, G. D., O nekotorykh voprosakh petrografii v svyazi s metallogenicheskimi obobshcheniyami. [CERTAIN PROBLEMS OF PETROGRAPHY ASSOCIATED WITH METALLOGENIC GENERALIZATION]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1950.

4. Afanas'yev, G. D., Osnovnyye itogi izucheniya magmaticheskoy geologii Severo-Kavkazskoy skladchatoy oblasti. [BASIC RESULTS OF A STUDY OF THE MAGMATIC GEOLOGY OF THE NORTH CAUCASUS FOLDED ZONE]: Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1956.

5. Afanas'yev, G. D., O kaynozoyskom magmatizme Kavkaza i o nekotorykh itogakh opredeleniya absolyutnogo vozrasta kavkazskikh porod K-Ar metodom. [CENOZOIC MAGMATISM IN THE CAUCASUS AND CERTAIN RESULTS OF THE DETERMINATION OF THE ABSOLUTE AGE OF CAUCASIAN ROCKS BY THE K-Ar METHOD]: Izv. Akad. Nauk SSSR, ser. geol., no. 6, 1957.

6. Afanas'yev, G. D., O nekotorykh geologicheskikh problemakh petrologii. [CERTAIN GEOLOGICAL PROBLEMS OF PETROLOGY]: Izv. Akad. Nauk SSSR, ser. geol., no. 11, 1957.

7. Afanas'yev, G. D., and S. G. Tseytlin, Predvaritel'nyye itogi izucheniya radioaktivnosti gornykh porod Severnogo Kavkaza i ikh znacheniye dlya nekotorykh problem petrologii. [PRELIMINARY RESULTS OF A STUDY OF THE RADIOACTIVE ROCKS OF THE NORTH CAUCASUS AND THEIR IMPORTANCE TO CERTAIN PETROLOGICAL PROBLEMS]: Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1958.

8. Afanas'yev, G. D., O zhil'nykh melanokratovykh porodakh na primere nekotorykh rayonov SSSR. [MELANOCRATIC LODE ROCKS AS EXEMPLIFIED IN CERTAIN REGIONS OF THE USSR]: Iz[illegible] Akad. Nauk SSSR, ser. geol., no. 12, 1958.

9. Afanas'yev, G. D., Geologiya magmaticheskikh kompleksov Severnogo Kavkaza i osnovnyye cherty svyazannoy s nimi mineralizatsii. [THE GEOLOGY OF TH[illegible] MAGMATIC COMPLEXES IN THE NORT[illegible] ERN CAUCASUS AND THE MAIN FEATURES OF THE ASSOCIATED MINERAL[illegible] ZATION]: Tr. In-ta geol. rudn. mestorozhd. petrogr, mineralogii i geokhimii Akad. Nauk SSSR, vyp. 20, 1958.

10. Afanas'yev, G. D., Nekotoryye geologiche[illegible] skiye rezul'taty issledovaniy absolyutnog[illegible] vozrasta gornykh porod. [CERTAIN GEOLOGIC RESULTS OF STUDIES OF THE ABSOLUTE AGE OF ROCKS]: Izv. Akad. Nauk SSSR, ser. geol., no. 9, 1959.

11. Afanas'yev, G. D., O petrograficheskoy interpretatsii geofizicheskikh dannykh o stroyenii zemnoy kory. [THE PETROGRAPHIC INTERPRETATION OF GEOPHYSICAL DATA RELATIVE TO TH[illegible] STRUCTURE OF THE EARTH'S CRUST] Izv. Akad. Nauk SSSR, ser. geol., no. 7, 1960.

12. Afanas'yev, G. D., R. N. Abdullayev, G. B. Bagdasaryan, K. G. Knorre, M. M. Rubinshteyn, and Z. V. Studenikova, Itogi geokhronologicheskikh issledovaniy magmaticheskikh gornykh porod Kavkaza [RESULTS OF GEOCHRONOLOGICAL INVESTIGATIONS OF MAGMATIC ROCK[illegible] IN THE CAUCASUS]: In the book, "Doklady sov. geologov k XXI sessii Mezhd. geol. kongr.", probl. 3 . Izd-vo Akad. Nauk SSSR, 1960.

13. Afanas'yev, G. D., Nekotoryye zakonomer[illegible] nosti razvitiya magmatizma skladchatykh oblastey SSSR. [CERTAIN DEVELOPMENT REGULARITIES RELATIVE TO THE MAGMATISM OF THE FOLDED ZONES IN THE USSR]: Izd-vo Akad. Nauk SSSR, 1960.

14. Afanas'yev, G. D., Stroyeniye zemnoy ko[illegible] i nekotoryye osnovnyye problemy sovremennoy petrografii. [THE STRUCTU[illegible] OF THE EARTH'S CRUST AND CERTAI[illegible] BASIC PROBLEMS OF CONTEMPORARY PETROGRAPHY]: Izv. Akad. Nauk SSSR ser. geol., no. 3, 1961.

15. Afanas'yev, G. D., and N. Kh. Aydin'yan, Predvaritel'nyye dannyye o rasprostranenii rtuti v gornykh porodakh Sever[illegible] onogoKavkaza. [PRELIMINARY DATA O[illegible] THE DISTRIBUTION OF MERCURY IN

THE ROCKS OF THE NORTHERN CAUCASUS]: Izv. Akad. Nauk SSSR, ser. geol., no. 7, 1961.

16. Barsukov, V. L., Novoye v geokhimii olova. [THE NOVEL FACTORS IN THE GEOCHEMISTRY OF TIN]: Congreso geologico internat. XX Sesion, Simposium de Exploracion Geoguimica (Prim. toma), Mexico, D. F. 1958.

17. Vorob'yeva, O. A., Shchelochnyye porody SSSR. [THE ALKALINE ROCKS OF THE USSR]: In the book, "Doklady sov. geologov k XXI sessii Mezhd. geol. kongr." Izd-vo Akad. Nauk SSSR, 1960.

18. Koptev-Dvornikov, V. S., I. F. Grigor'yev, Ye. I. Dolomanova, Ye. V. Negrey, O. S. Polkvoy, M. G. Rub, I. Ye. Smorchkov, and F. K. Shipulin, Granitnyye formatsii malykh glubin. [SHALLOW-DEPTH GRANITE FORMATIONS]: In the book, "Doklady sov. geologov k XXI sessii Mezhd. geol. kongr." Izd-vo Akad. Nauk SSSR, 1960.

19. Lebedev, A. P., Osobennosti magmaticheskikh protsessov i mineralizatsii v usloviyakh platform i drevnykh drevnykh shchitov. [THE PECULIARITIES OF MAGMATIC PROCESSES AND MINERALIZATION UNDER PLATFORM AND ANCIENT SHIELD CONDITIONS]: In the book, "Doklady sov. geologov k XXI sessii Mezhd. geol. kongr." Izd-vo Akad. Nauk SSSR, 1960.

20. Rabinovich, A. V., Zakonomernosti raspredeleniya aktsessornykh mineralov v granitoidakh različhnykh metallogenicheskikh zon. [THE DISTRIBUTION MECHANISM OF ACCESSORY MINERALS IN GRANITOIDS OF VARIOUS METALLOGENETIC ZONES]: In the book, "Magmatizm i svyaz' s nim poleznykh iskopayemykh." Gosgeoltekhizdat. 1960.

21. Smirnov, S. S., Zametki po nekotorym voprosam ucheniya o rudnykh mestorozhdeniyakh. [NOTES ON CERTAIN PROBLEMS RELATIVE TO THE DOCTRINE OF ORE DEPOSITS]: Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1946.

22. Smirnov, S. S., Nekotoryye obshchiye voprosy izucheniya rudnykh mestorozhdeniy. [CERTAIN GENERAL PROBLEMS CONCERNING THE STUDY OF ORE DEPOSITS]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1946.

23. Sudovikov, N. G., Usloviya endogennogo rudnoobrazovaniya v dokembrii. [THE CONDITIONS OF ENDOGENIC ORE FORMATION IN THE PRECAMBRIAN]: In the collection, "Zakonomernosti razmeshch. mestorozhd. polezn. iskopayemykh". Izd-vo Akad. Nauk UkrSSR, 1960.

24. Ustiyev, Ye. K., Okhotskiy tektono-magmaticheskiy poyas i nekotoryye svyazannyye s nim problemy. [THE OKHOTSK TECTONIC-MAGMATIC BELT AND A FEW PROBLEMS RELATED TO IT]: Sov. geologiya, no. 3, 1959.

25. Belt, Ch. Banks, Intrusion and ore deposition tion in New Mexico. Econ. Geol., vol. 55, no. 6, 1960.

26. Buddington, A. F., Granite emplacement with special reference to North America. Bull. Geol. Soc. America, vol. 70, no. 6, 1959.

27. Fairbairn, H. W., W. H. Penson, P. H. Hyrley, and R. F. Cormier, A comparison of the ages of coexisting biotite and muscovite in some paleozoic granite rocks. Geochim. et Cosmochim. Acta, vol. 19, no. 1, 1960

28. Lyons, J. B., Geology of the Hanover quadrangle, New Hampshire-Vermont. Bull. Geol. Soc. America, vol. 66, no. 1, 1955.

29. Turneaure, F. S., Metallogenetic provinces and epochs. Econ. Geol., Fiftieth anniversary volume, 1905—1955, P. 1, 1955.

30. Tuttle, O. F., L'origine et la classification des granites à la lumière des études expérimentales dans le système $NaAlSi_3O_8-KAlS_3O_8-CiO_2-H_2O$. Sci. Terre, N hors sér. 1955.

31. Wyart, J., and G. Sabatier, Transformation des sédiments argileux sous l'action de l'eau à températue et à pressions élevées. Application au phénomène de granitization. C r. Acad. sci. Paris. t. 248, no. 24, 1959.

32. Wyllie, P. J., and O. F. Tuttle, Melting in the Earth's Crust. Int. Geol. Cong. Rep. of XXI sess. Nord., pt. 18, 1960.

Institute of the Geology of Ore Deposits,
Petrography, Mineralogy, and Geochemistry
of the U. S. S. R. Academy of Sciences,
Moscow

Received, 22 June 1961

CERTAIN PROBLEMS IN THE METALLOGENY OF GEOSYNCLINES[1]

by

V. I. Smirnov

In the early 'twenties of this century a number of investigators concerned with regional geology pointed out the amazingly uniform succession of the complexes of magmatic rocks and associated endogenic deposits which accompany the transition of mobile geosynclines into relatively stable folded zones. Advantage was taken of this peculiarity to characterize the metallogeny of geosynclines on the basis of their historical and tectonic development. In our country especially interesting results in this direction were achieved by Yu. A. Bilibin. He has developed the general principles of metallogenic analysis, and a number of his followers applied them to specific metallogenetic provinces within the territory of the Soviet Union. It is well known that the general evolution pattern of magmatism and of ore-formation in the process of transformation of geosynclines into consolidated folded zones may be broken down into the following stages.

In the early, purely geosynclinal, stage of development, four main complexes of igneous rocks and accompanying magmatic deposits are formed: firstly, the volcanic complex of submarine spilitic-keratophyre and porphyritic rocks and their associated pyritic deposits; secondly, peridotite intrusions with their characteristic typomorphic magmatic deposits of chromites and osmium- and iridium-bearing chrome-spinels; thirdly, a complex of gabbro-pyroxenite-dunite rocks accompanied by magmatic concentrations of titanomagnetites, platinum, and palladium; fourthly, the plagiogranite and plagiosyenite intrusions of which skarn-type iron and copper ore deposits are so strikingly characteristic.

The middle development stage, corresponding to the period of the main folding phases, is marked by the formation of batholithic granitoid masses which usually may be divided into two rock groups. The first includes the moderately acidic granites of granodiorite subformation of the skarn-type deposits of which predominantly non-ferrous and rare metals are typical; and the second, the normal and excessively acid granites of alaskitic subformation which are everywhere closely associated with pegmatite, greisen, quartz-feldspathic, and quartz rare-metal deposits.

During the last transition stage of the mobile folded geosynclinal zone the platform is invaded by, so-called, minor intrusions of different composition, which are usually accompanied by powerful post-magmatic processes which are responsible for the formation of various deposits, including very large hydrothermal deposits mainly of sulfidic paragenesis.

The alternation of these complexes successively forming in the cross-section of the folded zones, is related to the regional zoning in the genetic and compositional distribution of various groups of deposits.

The orderliness and plausibility of the briefly outlined pattern of the metallogeny of geosynclines have turned many geologists into staunch apologists of this theory. However, further intensive inquiries into the formation and distribution mechanisms of endogenic deposits in folded systems revealed with ever growing clarity that these regularities reflect only the general trend of the processes of the evolution of magmatism and ore formation, without disclosing certain, sometimes very important, peculiarities in the metallogeny of geosynclines. This explains to a considerable extent the recent appearance in print of a fairly extensive controversy over the outlined scheme. Some of the views expressed by competent geologists reflect well grounded criticism. But there are also some hardly convincing statements made by unqualified individuals who are likely to go so far as to negate completely the existence of natural evolution in magmatic activity and ore accumulation in connection with the development of geosynclines. Yet, it suffices only to analyze carefully the formation sequence of igneous rocks and endogenic deposits in any geosynclinal system to be convinced that these phenomena

[1]Nekotorye problemy metallogenii geosinklinaley, (pp. 56-71).

actually do follow the described order of succession. Like any geologic process which is closely associated with the changing stages of lithosphere formation, this sequence is manifested differently at different formative stages in the various regions of the earth's crust, and has no universal meaning in this sense. Moreover, the described scheme, in itself, does not reveal any interrelations between magmatism and ore formation in the successive cycles of geologic development within one and the same minerogenetic province; nor does it indicate the general evolution of magmatism and ore accumulation in the history of the formation of the earth's crust from the ancient to the recent stages. Neither does it not permit the geosynclines to be differentiated according to types of magmatism or of ore formation, or determine the peculiarities of these processes for the different structural constituents of folded zones.

All of these and other features inherent to the study of the regional formation and distribution characteristics of the endogenic deposits of commercial minerals pose difficult problems in the complex sphere of the metallogenic analysis of geosynclines. And yet, they have not only a theoretical but also an important practical significance in formulating the scientific principles for the preparation of estimate and metallogenic maps being compiled everywhere in our country.

This paper discusses the extent of our knowledge with respect to some of these aspects of metallogenic analysis. The level of our knowledge is, apparently, insufficient to unravel completely the problems at hand and merely suggests certain lines for further investigations.

THE POLYCYCLIC CHARACTER, HEREDITY, AND METALLOGENIC SPECIALIZATION OF MINEROGENETIC PROVINCES

If one is to approach the definition of a minerogenetic province from a broad viewpoint in visualizing it as a major folded zone formed because of the successive disappearance of geosynclines, then all minerogenetic provinces should be considered as polycyclic. This means that, within their limits the products of magmatic activity manifested during several successive cycles of geologic development, several metallogenetic epochs may be found to occur together over large areas located in the same territory. If one is to consider only the decisive metallization epochs, then for the territory of our country one should note the presence of Mesozoic and Alpine mineralization in the far Northeast; that of the Hercynian, Mesozoic, and Alpine epochs in the Zabaykal'ye-Primory'ye regions; of Caledonian and Hercynian epochs in the Urals, Kazakhstan, and Central Asia; of Proterozoic, Sinian, and Caledonian epochs, in the Altay-Sayan folded zone; of Caledonian, Hercynian, Mesozoic, and Alpine epochs, in the Caucasus

It is perfectly obvious that in such polycyclic provinces there is not merely a repetition of the general cycles of magmatism and mineralization, but a more complex development of these phenomena reflecting the general evolution of geologic processes from the very ancient to the more recent cycles. However, the conditions and the forms of transition from geosynclinal systems of the preceding cycles to the subsequent cycles of geologic development are known to have been very inadequately studied. Most authorities in the field of geotectonics agree on only four characteristics of these transitions. First, they agree that the geosynclines, at least of the Caledonian, Hercynian, Cimmerian, and Alpine cycles, developed within the confines of one geosynclinal region of the earth which has been successively contracted in area because of partial loss of mobility and partial attachment to the platform; secondly, that the complexity of the geosyncline outlines increased from the ancient to the younger development cycles; thirdly, that the primary geosynclines of the subsequent cycles were emplaced over the remnants of the troughs of previous cycles and inherited them in their subsequent development; fourthly, that in this connection the internal zones of the new geosynclines usually were shifted away from the medial uplifts developed on the sites of the inner geosynclinal zones of the preceding development cycle. At the same time, the general evolution of sedimentation, magmatism, and ore formation during the transition from one cycle to another within the confines of the same region have been very poorly investigated.

At present, it is very difficult to say anything about the qualitative aspect of the changes in magmatism during the transition from one development cycle to another. As to the quantitative aspect, for a number of provinces a general reduction in the volume of magmatic activity is to be noted as opposed to the growing scale of magmatic ore formation accompanying the transition from the preceding to the subsequent cycles of geologic development.

Another important characteristic is the inherited development of the deposits of typomorphic metals in a large number of polycylic metallogenetic provinces. For example, typomorphic for the Caucasus are deposits of copper, molybdenum, and partly of polymetals occurring among the formations of the Caledonian, Hercynian, Mesozoic, and Alpine metallogenetic epochs; in the Zabaykal'ye-Primorye metalligenetic province, tin deposits which were found to be associated with the Pre-Paleozoic, Lower Paleozoic Hercynian, Mesozoic, and Alpine epochs; in the far northeast, gold and tin

deposits related in origin to the Upper Jurassic and the younger Upper-Cretaceous — Tertiary metallogenetic epochs; and in the Urals, iron deposits which literally dominate all magmatic processes from the ancient Pre-Paleozoic to the Hercynian epoch during which ore formation was terminated in this province. The deposits of typomorphic metals recur from epoch to epoch, not only for the provinces as a whole, but also often for their individual zones.

The repetition of the mineral composition of endogenic deposits in most cases cannot be attributed to the redeposition of the metallic substance from ancient deposits during the formation of subsequent younger deposits. Only in individual, and probably very rare, cases, such redeposition may have taken place as a result of the capture of the substance from ancestral deposits and its regeneration in the ore showings of subsequent epochs.

Metallogenic investigations in polycyclic minerogenetic provinces in our country, and in other parts of the world, show that prevalent throughout these territories are different types of deposits of definite typomorphic metals which confer a specific metallogenic coloration to each province. The accumulation of the ores of these metals, as stated earlier, continues from one epoch to another and attests to the lasting geochemical stability of the plutonic ore-generating processes in many provinces. The clarification of the reasons for such a stable specialization in the metallogeny of many minerogenetic provinces is a problem of primary importance. Its solution will be found in working out the intricacies of the general problem of geology — the investigation of the composition, structure and processes of the deep-seated parts of the earth's crust and the subcrustal area.

EVOLUTION OF MAGMATISM AND ORE FORMATION FROM ANCIENT TO RECENT GEOLOGIC CYCLES

The territory of our country is remarkable from the geological point of view because it encompasses folded zones with igneous rocks and endogenic deposits belonging to all cycles in the development of the earth's crust. The location of complexes of rocks and ore minerals formed during the Archean (or several Archean), Proterozoic (or several Proterozoic), Sinian, Caledonian, Hercynian, Mesozoic, and Alpine geologic cycles, is generally known.

The Archean epoch is represented by deposits of the Pre-Paleozoic platforms and individual massifs of the oldest rocks known in the folded zones belonging to the more recent cycles of development. The most characteristic areas of this type are the Baltic and the Ukrainian shields of the Russian platform, the Aldan shield, the Anabarskiy massif, the Yenisey uplift, and the eastern part of Eastern Sayan in the Siberian platform. During the formation of the Archean, magmatic rocks, palingenetic processes, highly unfavorable for ore generation, predominated. This is the reason that the Archean deposits are mainly metamorphogenetic of the ferruginous quartzite type. Of the magmatic deposits, only the ceramic and micaceous pegmatites are of any importance.

The Proterozoic and Sinian epochs are still undifferentiated metallogenetically. Deposits of these epochs are found, first of all, in areas where Archean complexes developed and covered them in large areas. Secondly, they occur in the vast territory occupied by the Baykalian Vitim and Stanovik folded complexes. Thirdly, they occur in large areas of the Altay-Sayan folded zone. Identified for these epochs everywhere are the older rock groups belonging mostly to the gabbro-pyroxene-dunite and plagiogranite complex, and the later intrusions of acid rocks which may be subdivided into the granodioritic phase and the subsequent phase of granites and alaskites. The minor intrusions of the concluding stage of magmatism in these epochs were not identified. The most characteristic of these are: 1) magmatic deposits of basic magma represented by ilmenite-magnetitic ores and sulfidic copper-nickel formations; 2) micaceous pegmatites of acid magma; 3) hydrothermal pyritic and auric deposits.

The Caledonian metallogenic epoch turned out to be the concluding epoch for the Altay-Sayan folded zone and the forerunner for most of Kazakhstan, the northern zones of the Tien-Shan and the Western Urals. Endogenous deposits dating back to this epoch occur also in the massifs of the ancient folded complexes in other, Hercynian and younger, provinces (the Caucasus, Transbaykal and Amur districts, the far Northeast). Peridotite intrusions are poorly developed in the Caledonian provinces. Rocks with gabbro-pyroxene-dunite and plagiogranitic composition are more abundant. Occurring with equal frequency are the moderately acid granitoids and acid granites which followed them. Minor intrusions of the concluding stage in the Caledonian cycle are manifested in the form of hypabyssal alkali-rock plutons in Eastern Sayan. The time of their formation here was not fixed precisely. Expecially characteristic for this epoch are: 1) magmatic ilmenite-magnetite deposits, 2) skarn-type iron-ore deposits; 3) various hydrothermal deposits of gold in quartz veins, pyrites, and skarns.

The Hercynian metallogenic epoch is distinguished by an unusual variety of intrusive complexes, by the diversity and richness of the endogenic ore deposits, and stands out conspicuously among the relatively limited types of mineralization originated in the preceding and

subsequent periods. These deposits are found in the Urals, in Kazakhstan, Central Asia, the southern part of the Taymyr, in the Tom'-Kolyvan' zone, as well as in the Paleozoic massifs in the regions of Mesozoic-Cenozoic folding.

In conformity with the peculiarities of geologic development in the individual provinces, the Hercynian epoch is marked by early intrusions of peridotites, gabbro-pyroxenite-dunites, and plagiogranite-syenites manifested with different degrees of intensity. Traceable everywhere is the complex of granodioritic rocks accompanied by a subsequent complex of acid granites. Minor intrusions of the concluding development stage may be discerned distinctly in several places. Significant and diversified deposits typify this epoch. They include: 1) magmatic chrome deposits associated with the peridotites of the Urals; 2) magmatic titanomagnetite and platinum deposits located among the rocks of gabbro complex; 3) skarn-type deposits of iron and copper associated with the plagiogranite-syenite intrusives; 4) skarn-type polymetallic and tungsten deposits coinciding with highly-basic granitoids; 5) pegmatitic, greisen-quartz, and quartzitic deposits of tin, tungsten, and molybdenum, originated by intrusions of granites and alaskites; 6) hydrothermal, predominantly polymetallic and cupric stages of minor intrusions. In addition to these, there are also Hercynian deposits of the platform development stage, for example, in the Baltic shield, which will not be discussed in this paper.

The Mesozoic metallogenic epoch is exceptionally peculiar in so far as magmatic evolution is concerned. Here, one observes what appears to be a reverse sequence in the development of the deep-seated magmatic complexes and associated deposits. First to develop in the early stages were the minor intrusions (for example, the pre-batholithic Kolyma complex, intruded after them were the acid granite rocks, and then the moderately acid granitoids, which are particularly well developed in the Eastern Transbaykal area. Rocks of peridotitic, gabbro, and plagiogranitic complexes are totally uncharacteristic of the Mesozoic epoch. Deposits of this epoch are found within the limits of the far Northeast, the Caucasus, and in the Transbaykal-Amur district. The most essential of these are: 1) hydrothermal gold deposits associated with the early minor intrusions and the most recent granitoids; 2) pegmatitic, greisen and quartz deposits of tin, tungsten, and other metals associated with acidic granite rocks; 3) skarn-type and hydrothermal deposits of polymetallic ores, copper, arsenic (arsenopyrite), molybdenum, tungsten, and barite, and the concomitant intrusions of moderately acidic granitoids.

The Alpine metallogenic epoch is characterized by the deposits of the far Northeast, the eastern part of the Transbaykal-Amur district, the Caucasus, the Carpathians, and the Kopet-Dag. No clear-cut and pervasively uniform evolution can be noted for this epoch in the process of formation of igneous rocks and associated endogenic deposits. A few local provincial sequential patterns of intrusion by magmatic complexes, mostly of granitoid rocks, are known. Intrusions of gabbro, and particularly peridotite, composition are not characteristic, although they are found locally (Sevan-Kurdistan zone of the Caucasus). Major intrusions of acid rocks are diversified, irregular, and often incomplete, alternating with minor intrusions. Most typical of this epoch are various hydrothermal deposits; and skarn-type deposits of iron and polymetallic ores also occur.

Thus, while the general evolution pattern of magmatism and ore-formation is retained, the history of each period shows some specific deviations, which make it possible to evaluate the different intensities in the formation of igneous rock complexes originating in the successive stages of the geologic cycle from the ancient to the youngest metallogenic epochs (Figure 1). This fact, in turn, leads to a varying development intensity of the genetic types of endogenous deposits for different metallogenic epochs (Figure 2).

A combined analysis of these two development patterns permits a judgement to be passed on the evolution tendencies of magmatism and magmatogenetic ore formation from the most ancient to the most recent stages of development of the earth's crust. It becomes apparent thereby that the early stage peridotitic intrusions are poorly manifested in all cycles except the Hercynian, and then only in the Ural geosyncline. The intrusives of gabbro-pyroxenite-dunite composition and the derivative plagiogranite rocks developed in ever-increasing proportions from the Proterozoic cycle to the Hercynian when this activity diminished rather abruptly. The moderately acid granitoid complex was more or less stable throughout all epochs. The alaskitic granites developed at an even pace from the very ancient epochs to the Mesozoic, but in the Alpine cycle, appreciably decreased in volume. Finally, the minor intrusions of the concluding stage of development manifested themselves distinctly only with the advent of the Hercynian period and were predominant in the Alpine epoch.

The irregularity in the development of magmatic complexes led to irregularities also in the formational intensity of various genetic classes of ore deposits. Commercial magmatic chromite deposits of peridotitic magma are noted only for the Hercynian epoch. Magmatic deposits of titanomagnetites and the skarn-type iron and

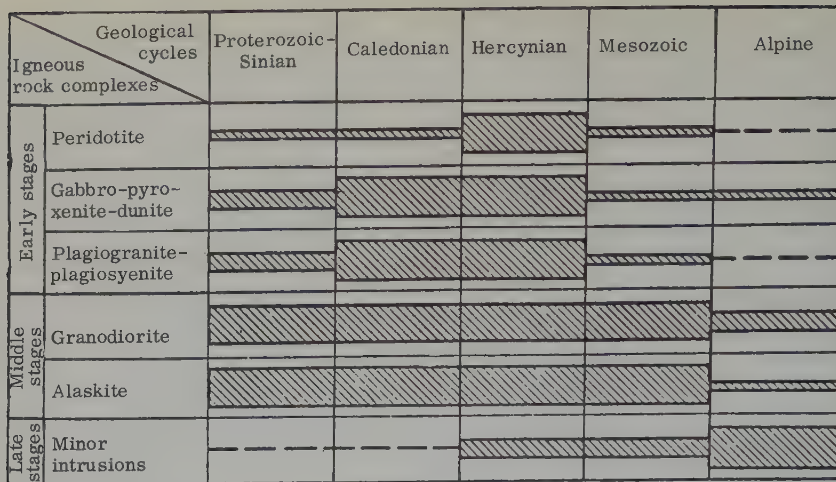


FIGURE 1. Development intensity of igneous rock complexes according to stages of the geosynclinal cycle and metallogenic epochs

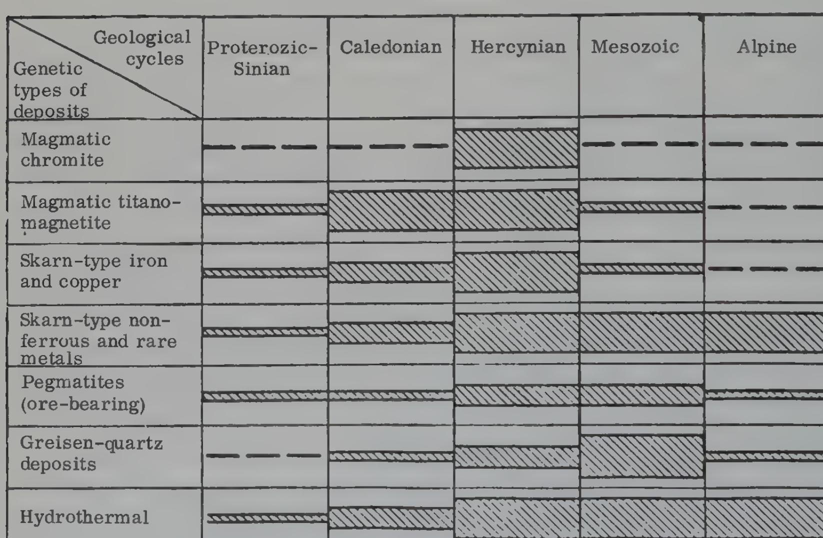


FIGURE 2. Development intensity of the genetic types of endogenic ore deposits for various metallogenic epochs

copper ore deposits formed in ever increasing proportions from the Proterozoic through the Hercynian epoch. Pegmatitic and greisen-quartz deposits belong to the most ancient in terms of their origin. However, prior to the Hercynian epoch, for the most part they contained groups of ceramic and micaceous materials, and deposits of rare metals are associated with them only in the Hercynian and Mesozoic epochs. The hydrothermal and skarn-type deposits of non-ferrous, rare, and noble metals were absent in the Archean, and appeared in minor amounts in the Proterozoic, Sinian, and Caledonian epochs, assumed vigorous proportions in the Hercynian epoch, and in the Mesozoic and Alpine epochs they continued to occupy a dominant position.

The general evolution tendency of magmatism and ore formation from the most ancient epochs to the recent ones may be reduced to the following pattern. From the Proterozoic epoch to the Hercynian there appeared well pronounced intrusions and endogenic deposits of the early

stage of geosynclinal cycles. In the subsequent epochs they became extinct to a considerable extent. From the Hercynian to the Alpine epoch, the role of minor intrusions and the associated postmagmatic deposits of the late stage of geosynclinal cycles increased in importance.

Thus, the Hercynian epoch turned out to be critical in the general history of magmatism and ore formation. It is distinguishable for the extensive development of all igneous rock complexes and various genetic groups of endogenic deposits. An important role in the composition of igneous rocks and mineral formations of the preceding epochs is played by the ultra-basic and basic rocks and deposits belonging to the early stages of the geologic cycles. Among the igneous rocks and mineral masses of the subsequent epochs the granitoid rocks with associated deposits are clearly predominant. This is, possibly, attributable to the fact that the development of geosynclines in the early cycles occurred on a relatively thin sialic shell which covered the basaltic substratum. Later, as the sediments continued to accumulate, the thickness of the shell has increased, and prevented the penetration of large ultrabasic and basic rock massifs even into the downwarping floor of the geosynclines. Of course, the outlined theory of the evolution of magmatism and ore formation is generalized for the territory of the Soviet Union as a whole. There are substantial deviations from this rule with respect to individual geosynclines.

GROUPING OF GEOSYNCLINES ACCORDING TO THEIR METALLOGENIC CHARACTERISTICS

The development of magmatism and endogenic mineralization in geosynclines, on the one hand following a single pattern, and on the other in terms of a system permitting differentiation of a definite series of geosynclines from other varieties, makes it possible to attempt their metallogenic grouping. But first of all it should be stated that there is no single classification of geosynclines suitable for these purposes. The well-known classifications of K. Schuchert, M. Key, and even that of V. E. Hann's are inadequate in this respect. Consequently, geologists working in the field of the metallogenic analysis of geosynclines have made several attempts to develop their own subdivisions. Yu. A. Bilibin distinguished the Uralian, the Far-Eastern, and the West European metallogenic types of geosynclines. Ye. A. Radkevic identifies the femic and sialic zones among the geosynclinal areas. Kh. M. Abdullayev has used the designations, activated geosynclines, polygeosynclines, mobile polygeosynclines with terminated magmatism, and monogeosynclines.

In an attempt to typify the geosynclines for purposes of metallogenic comparison, one might resort to a comparative analysis of the development peculiarities, structure, magmatism, and endogenic ore content of all linear folded zones available for this purpose. An attempt at such a comparison for the belts of folded structures in the U. S. S. R. showed that two factors are of the utmost importance for the metallogenic classification of geosynclines. First, the presence or absence of early magmatism in the geosynclinal development stage, which puts an indelible imprint on the entire metallogenic aspect of folded zones; second, for geosynclines with feeble initial magmatism, this is the character of the tectonic development of geosynclinal zones during the period of the main folding phases in terms of reversible or irreversible transformation of the geosyncline into a folded zone. On the basis of these criteria it is possible to identify four types of geosynclines which will be tentatively designated as types A, B, C, and D.

Type A Geosynclines form folded zones distinguished by intensive effusive and intrusive magmatism and metallogenic activity in the early stage of development. This type includes the Hercynian geosyncline of the Urals (Figure 3). Their geosynclinal bottom is broken down into a number of deep-seated trenches separated by uplifts.

In the first stage of geosynclinal development stage there was a relatively long period of subsidence in the trenches. During the second stage the bowing for a relatively short period of time affected also the space between the geosynclinal trenches. During the middle, folding stage of development anticlinoria formed over this expanse. These geanticlines separated the synclinoria which formed within the limits of the geosynclinal trenches. Abundant products of early magmatism and metallogeny here localized exclusively within the geosynclinal trenches and along their boundaries. The batholithic granite massifs and the associated postmagmatic deposits of the middle development stage, on the contrary, settled in the zones of the anticlinoria which separated the volcanic synclinoria. A metallogeny of granitoids with high basicity and alkalinity usually predominate. Minor intrusions of the late development stage and its associated postmagmatic deposits are not characteristic of such geosynclines. The cross-section of such geosynclines is characterized by well-pronounced regional metallogenic zoning.

Pyritic and skarn-type early stage iron and copper deposits are concentrated in the zones of volcanic synclinoria. In the geanticlinal zones hydrothermal deposits associated with the middle-stage granites are localized. Narrow belts of magmatic deposits extend along the boundaries of the geanticlinal zones following the tectonic fracture zones. These deposits

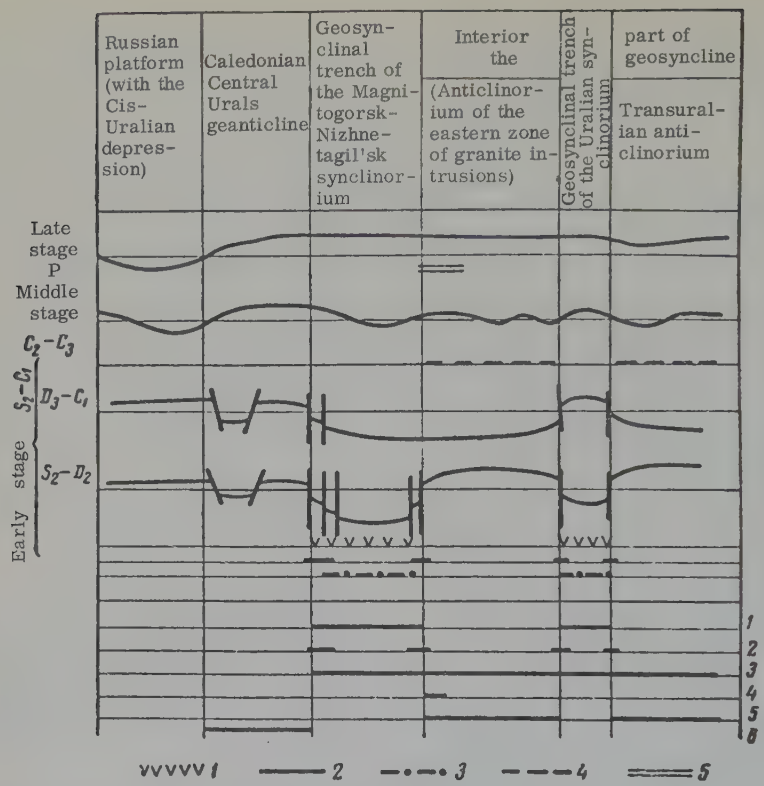


FIGURE 3. Diagram of the evolution of the Uralian Hercynian geosyncline, its magmatism and metallogeny

1 - Accumulation of Early Hercynian volcanic rocks and formation of its associated pyritic deposits; 2 - intrusion of the Early Hercynian ultrabasites and basic rocks and formation of its associated magmatic deposits of chromium ores, titanomagnetites, and platinoids; 3 - intrusion of the Early Hercynian plagiogranites and syenites and formation of the associated skarn-type deposits of iron and copper ores; 4 - intrusion of Middle Hercynian granitoids and formation of its associated skarn-type deposits of iron ores, pegmatites, and hydrothermal deposits of gold, arsenic, and tungsten ores; 5 - intrusion of the Late Hercynian minor intrusives. The figures in the diagram indicate: 1 - pyritic deposits; 2 - magmatic deposits of chrome iron, titanium, and platinum; 3 - skarn-type deposits of iron and copper; 4 - pegmatitic deposits; 5 - hydrothermal deposits of gold, arsenic, and tungsten; 6 - telethermal deposits of lead, zinc, and fluorine.

were formed by linear intrusions of ultrabasic and basic early-stage rocks and coincide to a considerable extent with the hydrothermal deposits produced by minor intrusions of the late stage.

Type B Geosynclines are characterized by intensive effusive magmatism and the early development stage metallogeny. They differ from the foregoing type by damped plutonic magmatism of these stages and the absence of important magmatic deposits. The Hercynian geosyncline in the Greater Caucasus is an example of this type. The evolution pattern of an open segment of this geosyncline is shown in Figure 4.

Two principal elements of regional metallogenic zoning are distinguishable in these geosynclines. The first consists of the volcanic zones of primary geosynclinal trenches and troughs enclosing the effusive pyritic mineralization. The second contains the granitoid zones of the geanticlines which are characterized by a pegmatitic-greisen mineralization profile in the inner sections, and by a hydrothermal sulfidic character of ore in the peripheral parts of the geosynclines. Disrupted zones of mixed mineralization marked by negligible and local magmatic ore showings of the early stage and more pronounced late-stage deposits occur in the boundary regions between the volcanic granitoid belts.

Type C Geosynclines are responsible for folded zones without substantial early magmatis

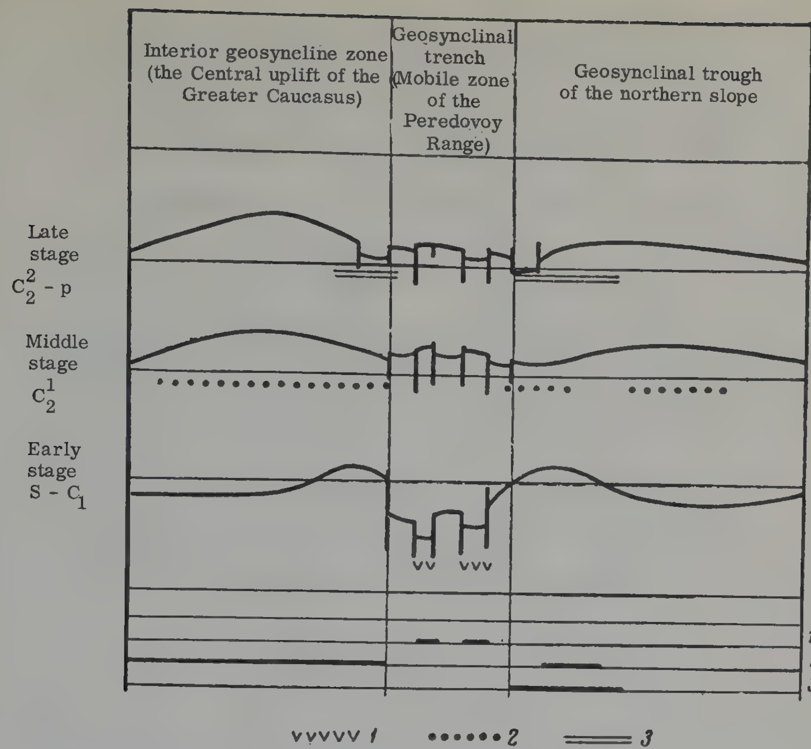


FIGURE 4. Diagram of the evolution of a segment of the Greater Caucasus Hercynian geosyncline, its magmatism and metallogeny

1 - Accumulation of spilitic keratophyres and formation of its associated pyritic deposits, as well as minor ultrabasic and basic intrusions containing manifestations of titanium, iron, and nickel ores; 2 - intrusion of granite rocks and formation of skarn-type, pegmatitic, greisen, and quartz deposits and ore showings of tungsten, molybdenum, tin and arsenic (arsenopyrite); 3 - penetration of minor intrusions and formation of its associated lead-zinc deposits. The figures in the diagram indicate: 1 - pyritic deposits; 2 - pegmatitic, greisen, less frequently skarn and hydrothermal, manifestations of tungsten, tin, molybdenum, arsenic, and gold; 3 - hydrothermal deposits of lead and zinc.

ıd metallogeny. The pattern of folding is inerted. The following geosynclines are exnples: The Cimmerian East Transbaykal eosyncline, the Hercynian geosyncline in the ien-Shan, and the Hercynian Zaysan geosynine in the boundary region between Eastern azakhstan and Western Siberia (Figure 5).

Structurally these geosynclines belong to the lassical type having a gentle inner trough in e early stage and its inversion into an axial plift during the middle stage of development. our distinct inner and peripheral zones may e identified in geosynclines of this type. hese zones differ in the composition of bedded rmations, their thickness, magmatism, and etallogeny.

The surface and deep-seated magmatism of e early stage is sharply reduced in this type geosyncline. Batholithic magmatism and its ssociated mineralization of the middle stage developed in full volume. In this process, two groups of granitoids were spatially distinctly separated. The group of normal and excessively acid granites intruded the inner zone central uplift forming a well-pronounced median belt of pegmatitic, greisen, quartz-feldspathic, and quartz deposits. The group of granitoids with high basicity and alkalinity was emplaced on the limbs of the geosyncline and in its peripheral zones, forming symmetrical belts of skarn-type and hydrothermal deposits, primarily of sulfidic paragenesis.

Type D Geosynclines are distinguishable by markedly slackened early-stage magmatism and metallogeny, and also by the uninverted pattern of folding in the middle stage of their development (without inversion of the geosynclinal trough into a median uplift). This type includes the geosyncline of Sikhote-Alin' and Verkhoyansk belonging to the Pacific belt system (Figure 6).

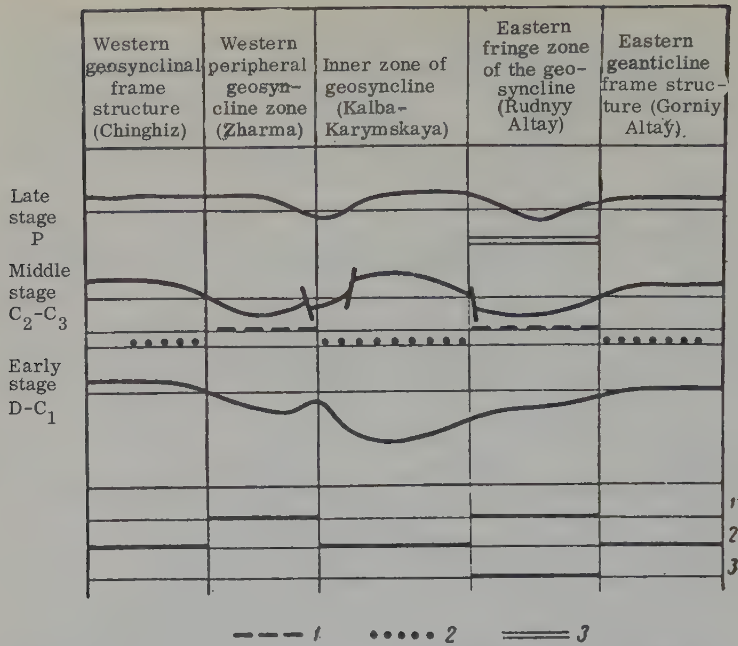


FIGURE 5. Diagram of the evolution of the Zaysana Hercynian geosyncline, its magmatism and metallogeny

1 - Intrusion of the Zmeinogorsk granitoids with high basicity and alkalinity and formation of its associated skarn-type iron and copper ore manifestations; 2 - intrusion of alaskitic granites of the Kalbinskian complex and formation of its associated pegmatitic and greisen deposits of tin, tungsten, and molybdenum ores; 3 - intrusion of the Rudniy-Altayan series of minor porphyric and porphyrites and formation of its associated pyritic polymetallic deposits. Figures in the diagram indicate: 1 - skarn-type iron and copper deposits; 2 - pegmatitic and greisen deposits of tin and tungsten; 3 - hydrothermal deposits of lead, zinc, copper, and gold.

This type of geosyncline usually developed according to a pattern inherited from the antecedent geologic cycles. In the early stage median uplifts or stable massifs of ancient rocks already existed in the inner zone of these geosynclines. The presence of these structures made it impossible for the geosyncline to develop into a folded zone following the pattern involving the inversion of the axial part of the geosynclinal floor into a central geanticline. The fringe zones of such geosynclines display a sharply nonsymmetrical development. The zone adjacent to the ancient platform is characterized by a passive tectonic state, weak magmatism, low ore content, and sometimes by early termination of development. Intensive tectonic, magmatic and metallogenetic processes were concentrated in the opposite fringe zone. The early-stage, deep-seated magmatic and volcanic processes were manifested in a very feeble form, producing no direct effect on the metallogeny of these geosynclines. Mineralization resulting from batholithic intrusions of the middle-stage granitoids is clearly inferior in scale to the mineral richness of the late-stage minor intrusions. The hypabyssal minor intrusions and its associated hydrothermal ore deposition occurred at least twice: prior to the injection of the granitoid batholiths and after the batholithic magmatism. T[he] regional metallogenic zoning is not distinctly discernible in the cross-sections of this type [of] geosyncline.

The characteristic metallogenic features [of] the various types of geosynclines are describ[ed] in Table 1.

THE METALLOGENIC CHARACTERISTICS OF THE TECTONIC SECTORS IN GEOSYNCLINES

It can now be quite definitely stated that a[n] orderly emplacement of uniform associations [of] endogenic deposits of commercial minerals i[n] the cross-sections of folded zones is caused [by] the localization of the corresponding magmat[ic] rock complexes appearing regularly during th[e] transformation of a geosyncline into consolid[ated] belts. However, this process does not invol[ve] the geosyncline as a whole, and takes place o[nly] in strictly defined tectonic sectors of geosyn[-] clinal systems. Thus, investigation of the metallogenic characteristics of the tectonic sectors in a geosyncline becomes a matter o[f]

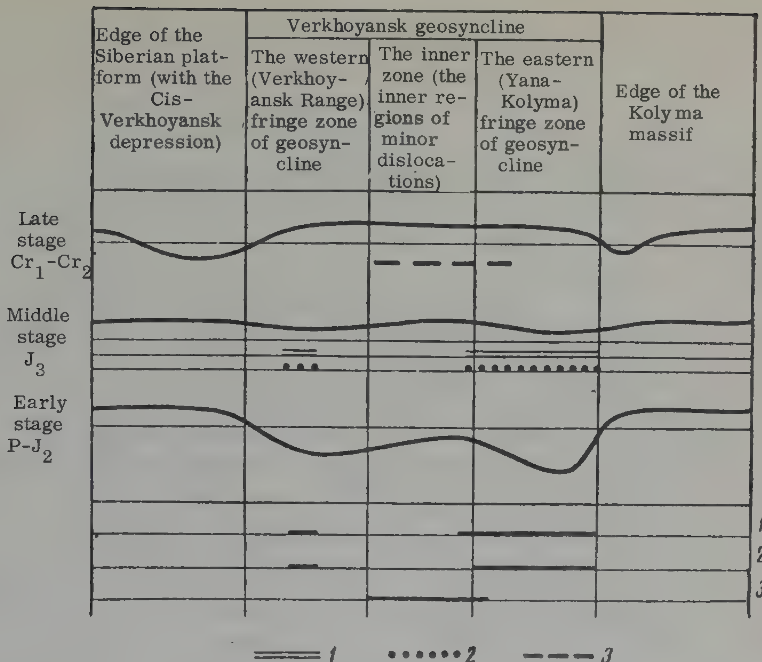


FIGURE 6. Diagram of the evolution of the Cimmerian Verkhoyansk geosyncline, its magmatism and metallogeny

1 - Intrusion of the minor intrusives of diorite-porphyrites and granite-porphyrites of the Pre-batholithic complex and formation of its associated hydrothermal auriferous deposits; 2 - intrusion of leucocratic Kolyma complex granites and formation of its associated pegmatitic and greisen deposits of tin, tungsten, and molybdenum ores; 3 - intrusion of the Omsukchansk complex granitoids and formation of its associated hydrothermal deposits of tin, tungsten, lead-zinc, arsenic, and cobalt ores. Figures in the diagram indicate: 1 - hydrothermal deposits of copper; 2 - greisen deposits of tin, tungsten, and molybdenum; 3 - hydrothermal tin, tungsten, lead, zinc, arsenic, and cobalt deposits.

eat importance. According to the views held V. V. Belousov, V. A. Nikolayev, A. V. Peyve, M. Sinitsyn and others the following can be stinguished: 1) the inner zones, 2) fringe nes, 3) geosynclinal trenches; 4) central assifs; 5) the geosynclinal frame structure; deep boundary faults.

The inner zone is characterized by the deep-t downwarping in the early stage and is not pical of all geosynclines. In the type-D geonclines, tectonically stable massifs replace e inner trough. In the A-type geosynclines it complicated by tectonic trenches. Clearly onounced inner zones are characteristic of e classic geosynclines of type C. It is presely in them that a well-defined inner trough velopes in the early stage of geosynclinal rmation. Toward the middle stage this ough turns into an axial uplift following the ttern of complete inversion.

The inner zones are distinguishable for nazingly clear and universally uniform magatism and metallogeny. Characteristic of ese is a single act of igneous rock intrusion and the formation of closely related endogenic deposits. These rocks are average and excessively acid alaskitic granites of middle folding stage forming thick zones of rare-metal deposits of pegmatitic greisen, and greisen-quartz origin.

The fringe zones do not display such an extensive and stable degree of downwarping in the early stage as is characteristic of the inner sections of geosynclines. They serve as an arena for the intrusion of large batholithic middle-stage granitoid massifs predominantly of moderately acid composition. Unlike the inner zone, the peripheral parts of the geosynclines are not distinguishable for a universally uniform magmatic-metallogenic characteristic. Nonethe less, they are also peculiarly associated with endogenic deposits represented mainly by skarn-type and hydrothermal ore manifestations of non-ferrous, rare, and noble metals, mostly of sulfidic paragenesis. This pattern of magmatism and metallization of the fringe zones is often complicated by superposition of late-stage magmatism and mineralization. Moreover, the fringe zones in the same geosyncline are rarely

Table 1

Certain Metallogenic Characteristics of Different Types of Geosynclines

Type of geosynclines	A	B	C	D
		DEVELOPMENT STAGES		
Early stage	Very pronounced	Sufficiently pronounced	Very pronounced	Cannot be differentiated in terms of stage types
Middle stage	Pronounced	Pronounced	Same	
Late stage	Indistinct	"	"	
	CONDITIONS OF GEOSYNCLINE TRANSFORMATION INTO A FOLDED ZONE			
Inversion of the middle stages	Partial inversion of the late Flysch troughs	Partial inversion of the late Flysch troughs	Total inversion	No inversion
		MAGMATIC PROCESSES		
EARLY STAGE				
Volcanic rocks	Well developed	Developed	Weak	Weak
Peridotites and gabbro	Same	Weak	"	"
Plagiogranites and plagiosyenites	"	Developed	Absent	Absent
MIDDLE STAGE				
With high basicity and alkalinity	Developed	Well developed	Well developed	Developed
Acid (granites)	Poorly developed	Developed	Developed	"
LATE STAGE				
Minor intrusions of different composition	Poorly developed	Developed	Well developed	Well developed
		PROBABLE ZONES OF MAGMATIC FEEDING		
Horizons of magma formation	Basaltic stratum passing into sialic layer	Intermediate layer passing into sialic layer	Sialic layer	Sialic layer passing into basaltic
		STRUCTURAL CHARACTERISTICS OF THE EARTH'S CRUST		
Thickness of the sialic shell	Small	Medium	Very considerable	Considerable
		INTENSITY OF MINERALIZATION		
Early stage	Well developed	Developed	Absent	Absent
Middle stage	Developed	"	Developed	Developed
Late stage	Very weak	Manifested	"	Well developed
		GENETIC TYPES OF DEPOSITS		
EARLY STAGE				
Pyritic	Well developed	Developed	Absent	Absent
Magmatic	Same	Not developed	Absent	"
Skarn-type	"	Developed	"	"
MIDDLE STAGE				
Skarn-type	Well developed	Well developed	Well developed	Not developed
Pegmatitic and greisen-type	Not developed	Weakly developed	Developed	" "
LATE STAGE				
Hydrothermal	"	Same	"	Well developed

(Table 1 continued)

Type of geosynclines	A	B	C	D
	REGULARITIES OF DEPOSIT EMPLACEMENT			
Regional zoning	Distinct Characterized by alternation of three types of zones: 1) volcanic with pyritic and skarn-type copper and iron ore deposits; 2) ultrabasic and basic with magmatic iron, titanium, chrome, platinoid ore deposits; 3) granitoid with skarn-type and hydrothermal deposits of iron, gold, and other ores.	Fairly distinct Characterized by alternation of two types of zones: 1) volcanic with pyritic copper, and zinc ore deposits; 2) granitoid with hydrothermal deposits of copper and molybdenum ores.	Fairly distinct Characterized by alternation of three types of zones: 1) internal granitic with pegmatic and greisen-type deposits of tin and tungsten ores; 2) peripheral with hydrothermal deposits of iron, gold, non-ferrous and rare metal ores; 3) geosynclinal frame with complex mineralization of the middle, and sometimes, the late stages of development. Complicated by superposition of late-stage mineralization.	Indistinct Metallogenic ore zones with varying compositions associated with magmatic complexes of the middle and late development stages and in varying degrees over lapping each other.

f the same type. Frequently they vary slightly n terms of ore content creating an asymmetric attern in the metallogenic zoning of folded elts.

The geosynclinal trenches represent, as it s well known, relatively narrow furrows ounded by major abyssal faults or series of aults. In the early stages of geosynclinal levelopment the beds of these trenches subsided steadily along the fractures. This process was accompanied by the filling of the roughs with submarine volcanic-sedimentary rocks. These trenches are characteristic of he geosynclines of type A and B.

Characteristic of the tectonic trenches are wo complexes of magmatic rocks and associated endogenic deposits: 1) the volcanic complexes are mostly of spilitic-keratophyre composition and contain pyritic deposits, and 2) he intrusive plagiogranitic-syenitic complexes elonging to the acid differentiate of basaltic nagma are accompanied by skarn-type deposits of iron and copper ores.

The Central massifs may contain the mineralization of three different periods: 1) of the ntecedent cycles; 2) of the cycle coetaneous vith the metallogenic epoch of the folded zone, nd 2) superimposed in connection with the regeneration which took place during the subsequent cycles of development. In analyzing the character of the mineralization in the central rock massifs which corresponds to that of the enclosing folds, it appears necessary to identify two types of massifs. The central of the first type are situated in the inner zones of geosynclines, while the massifs of the second type are enclosed by the geosynclinal ring from all sides representing the edge of the closed geosynclines. Typical of the central massifs of the first type which form the axial uplifts are extrusive rocks with pertinent deposits, i. e., leucocratic granites with their associated rare-metal pegmatites, greisens, and quartz veins containing tin, tungsten, and other rare metals. The second-type central massifs have the same magmatic and metallogenic features as the geosynclinal frame structures.

The geosynclinal frame of certain folded zones, along with the deposits originated in the preceding metallogenic epochs, also includes deposits characteristic of the geosyncline which is encompassed by the frame. Such superimposed mineralization may sometimes spread out onto the continent some 50 to 70 km from the geosyncline boundary. The width and intensity of such mineralization depends on the intensity of the tectonic and magmatic regeneration of the edge portions of the geosyncline by the stresses appearing at different stages, and their transformation

results from the movements occurring in the geosyncline.

On this basis four types of mineralization encountered in the geosynclinal frame may be identified: 1) the intensively regenerated type with manifestations of magmatism and mineralization of all stages known for a given geosyncline; 2) the moderately regenerated type with manifestations of magmatism and mineralization of one of the stages known for this geosyncline; 3) feebly regenerated with manifestations of telethermal mineralization of the late stage; 4) without igneous rocks and endogenic deposits.

Abyssal boundary faults are known to separate the structure-facies zones in geosynclines. They determine the sediment thickness and composition ratio in these zones during their formation. The more distinctly pronounced deep faults represent fractures which delineate the above tectonic elements of geosynclines. The boundary faults in penetrating to considerable depth, permit the intrusive rocks to spread out along them in causing the formation of the pertinent zones of endogenic mineralization. Comparison of the magmatism and metallogeny of such zones in quite different provinces discloses a very curious fact which evidences that their formation takes place only at the early and late stages of development. This important feature corresponds to the conditions of expansion prevalent in the early and late stages which are separated by compression in the middle stage of geosynclinal development.

At the early stage of geologic development intrusions develop along the boundary fractures of igneous rocks containing peridotite and gabbro-pyroxenite-dunite composition, forming magmatic deposits of chromite, titanomagnetites, and platinoids. At the late stage the deep boundary faults become the arena for the minor intrusions responsible for hydrothermal deposits. Because of the different proportions of early and late stage magmatism and mineralization along the abyssal faults, mineralized zones of different composition develop. One may distinguish among them zones with combined and simple composition. It is important to state, however, that very frequently, the mineralized zones which originated along the deep boundary fractures belong to the simple variety, with clear predominance of deposits formed either in the early, or in the late stage of developmen This is natural, since the intensive developme of magmatism and mineralization in the early stage damps the magmatic and ore-forming processes of the late stage, and vice versa.

In conclusions, we must still point out the fact that some of the materials considered in this article for the analysis of certain peculiarities relative to the metallogeny of geosynclines pertain only to the folded zones of the U. S. S. R. There is no doubt, that the inclusion of data on the metallogeny of the folded zones in other parts of the world — where thes problems, alas, are being studied rather sluggishly — may cause the authors to revise, and, possibly quite substantially, some of the positions taken in this paper. Furthermore, this article deals only with certain aspects of the broad problem of metallogeny and leaves some of its other facets to await future elucidation.

Moscow State University

Received, 20 April 1962

[T]HE AGE OF METEORIC BODIES AND OF THE EARTH ACCORDING TO RADIOACTIVITY DATA[1]

by

I. Ye. Starik and Ye. V. Sobotovich

[T]he problem of the age of the earth is closely [rel]ated to the theories of its origin and develop[men]t. A successful solution of this problem is, [th]erefore, unthinkable without a complex [ana]lysis of terrestrial and cosmic matter. Ac[cor]ding to the cosmogonic theories, the age of [the] earth should be reckoned from the moment [of i]ts formation as an isolated system. In [cal]culating the age of meteorites it is also nec[ess]ary to agree on what moment should be con[side]red as the starting point of their existence.

[R]adioactivity methods are believed at the [pre]sent time to be the most reliable for absolute [age] determinations. Since the rate of radio[acti]ve decay is constant in the thermodynamic [con]ditions of the earth, the accumulation of its [sta]ble products may serve as a measure of [tim]e. To determine the age of the earth or any [met]eoric substance one may conveniently use [the] decay of any natural radioactive element, [pro]vided its average life is comparable with [the] life span of these bodies.

[I]n order to relate the age values obtained for [met]eoric substances to the age of the earth, it [is m]andatory that the meteorite and the earth [bel]ong to the same system. Yet, at the present [tim]e, certain data have come to hand which [cas]t doubt on the validity of the above condition [wit]h respect to all meteorites without exception.

THE UPPER AND LOWER LIMITS OF THE EARTH'S AGE

[T]he principles of the radioactivity methods [of] age determinations of the earth and for [geo]logic formations are identical. However, [the]re is a basic difference between them

[I]n determining the age of rocks and minerals [we] begin the chronology from the moment of their [cry]stallization to the moment of sampling. During this entire period the rocks and minerals remain in a solid state, and if secondary processes occur they vanish without a trace. In the case of the earth, however, we know neither the starting moment nor the condition of the substance at that time. Consequently, this matter is hypothetical. Thus, we can speak definitely only of the lower age limit of the earth which is the age of the oldest sections of the earth's crust. This limit is most important to the development of geologic concepts. Hence, the age determination of the oldest rocks and minerals should be the first step in the study of the earth's age.

Today we know of some sections of the earth's crust (in Northern Kareliya and in South Africa) the age of which is estimated at about 3.5 billion years. If this is a fairly accurately established lower age limit of the earth, then its upper age limit can be determined by estimating the time of formation of the elements in terrestrial matter. Usually this is being determined on the basis of hypothetical postulates according to which the given elements are fully radiogenic and the Clarkes of the parent and daughter elements are well known to us. The first assumption makes it possible to consider the age to be determined as the upper age limit of the elements. However, inadequate confidence in the Clarke values of the mother and daughter elements can totally distort this age limit.

F. Houtermans [19], on the basis of H. Suss' and H. Urey's data [31] has plotted a distribution curve of the odd-odd nuclei as a function of the mass number. The only isotope whose period of half-life is comparable to the time of the earth's existence, and which is not located on this curve, is K^{40}. It falls below the curve since at the present time a considerable proportion of it is already in a state of decay. On this basis F. Houtermans has calculated the time when K^{40} was still subject to the general rules governing the abundance of odd-odd nuclei. The result was 4.5 to 5.3 billion years. Similar age computations based on the isotopic composition of uranium at the present time and at the moment of nuclei synthesis were made by

[1] Vozrast meteornykh tel i zemli po radio[akt]ivnym dannym, (pp. 72-83).

different authors on the assumption that no appreciable isotope separation is to be expected under natural conditions. The age value amounted to 4.5 to 6.6 billion years. V.I. Baranov [1] and V.V. Cherdyntsev [9] believe that the age of the elements is 5 to 6 billion years.

THE AGE OF THE EARTH ACCORDING TO TERRESTRIAL MATTER

It is generally assumed that there was a negligibly short period of time between the moment of the earth's formation and the origination of the lithospere, as compared to the lifetime of our planet. Consequently, the dates which characterize these two stages in the history of the earth must coincide. However, it is difficult to establish the validity of this position at the present time. Of the methods of determining the earth's upper age limit, the radioactive method based on the Pb^{207}/Pb^{206} ratio, proposed independently by I. Ye. Starik [6] and S. Meyer [23] in 1937, is considered to be the most reliable at present.

If one is to assume that lead isotopes having masses 207 and 206 are of entirely radioactive origin, then the age of the earth, as calculated by I. Ye. Starik, is equal to 5.0 billion years (calculated on the basis of the current value of λ AcU).

The question of the origin of various lead isotopes was considered debatable for a long time. The relatively great abundance of lead in the earth's crust inevitably led to the idea that most of it is of radioactive origin. However, on the basis of the modern theories, it is difficult to associate the origin of Pb^{204} isotope with radioactive disintegration. Thus, one must recognize that the proportion of non-radioactive lead is considerable. A. Nier [25], in determining the isotopic composition of lead in various types of galena noticed a sharp difference in the isotopic composition of lead from one sample of galena (Ivigtut) which was characterized by high abundance of Pb^{204}. Later on, the isotopic composition of lead in this variety of galena was used by many authors as a measure of primeval lead. The first steps in this direction were made by E.K. Gerling [4].

A study of the isotopic composition of lead separated from iron meteorites was of considerable interest since their uranium and thorium content is very small and the admixture of radiogenic lead should have, consequently, been negligible. It is true that until recently sufficiently accurate data on the content of uranium, thorium, and lead in iron meteorites was not available. The figures recently obtained on the lead content in iron meteorites (Table 1) show that the earlier views were not entirely correct. The proportion of lead in iron meteorites was assumed to be of the order of 10^{-6} g/g. Meteorites having a very low lead content ($2 \cdot 10^{-8}$ g/g) are known at the present time, and cases are possible where the admixture of radiogenic lead may turn out to be comparable in magnitude to the amount of lead considered as primeval.

On the basis of the presently available data on uranium content in iron meteorites ($1 \cdot 10^{-9}$ g/g) [8, 21], it is possible to consider that the radiogenic lead content is very low.

Determinations of the isotopic composition of lead separated from a number of iron meteorites (Table 1), indicate that there are at least two types of lead isotopic compositions. The first type agrees with the theoretical calculations of some authors [14, 19], whereas the second type corresponds to ordinar lead of terrestrial origin.

As a result of investigations of iron meteorites with varying structure — see Table 1 — it is possible to arrive at the following conclusions [7].

1. The 14 tested samples of iron meteorites can be divided into two groups according to the isotopic composition of lead contained in them: the first (5 meteorites) contains primeval lead; the second (9 meteorites) contains ordinary lea No intermediate isotopic composition has been revealed. These data speak in favor of the existence of at least two parent meteoric bodies.

2. The lead content in the tested meteorites differs from sample to sample within limits ranging from $2 \cdot 10^{-8}$ to $4 \cdot 10^{-7}$ g/g, with the meteorites displaying a concentration of $n \cdot 10^{-8}$ g/g (6 samples) containing ordinary lead, and those with a concentration of $n \cdot 10^{-7}$ g/g (8 samples) comprising both the primeval and the ordinary isotopic compositions of lead.

3. The distribution of lead in certain meteorites (Chinge, Sikhote-Alinskiy, Santa Catarina) is uneven, varying within the limits c one order.

4. No definite relationship between the stru ture of meteorites and the contents of the isotopic composition of lead is detected.

5. The lead content in troilites is 1-2 orde higher than in the iron-nickel phase. The isotopic composition of lead contained in troilites is analogous to that observed in the iron-nickel phase. The troilite-type inclusion in the Bishty meteorite is an exception. Here the lead has a ordinary composition but contains primeval lea in the metallic phase.

It is quite possible that further analyses ma reveal leads with isotopic composition other than that identified to date. It is, therefore,

Table 1

Lead Content in Iron Meteorites

Sample No.	Meteorite	Lead 10^{-7} g/g	Isotopic composition of lead					
			$\frac{206}{204}$	$\frac{207}{204}$	$\frac{208}{204}$	$\frac{206}{204}$	$\frac{206}{207}$	$\frac{206}{208}$
1	Devil's Canyon, coarse-textured anatase	1.4	9.43	10.58	29.80	9.43	0.981	0.316
2	Burgavli, anatase	2.4	9.34	10.58	30.28	9.34	0.887	0.308
	Troilite	76.6	9.79	10.68	30.27	9.79	0.917	0.323
3	Toluka, medium-texture anatase	1.6	9.87	10.70	30.36	9.87	0.914	0.325
4	Arus, medium- to finely-textured anatase	1.7	10.14	10.97	30.18	10.14	0.925	0.336
	Troilite	23.0	10.01	10.85	30.78	10.01	0.928	0.325
5	Bishtyube, coarse-textured anatase	1.8	9.80	10.74	30.08	9.80	0.913	0.326
	Troilite (?)	75.0	17.92	15.47	38.40	17.72	1.145	0.461
6	Avgustinovka, anatase, medium- to fine-texture	1.9	16.80	15.20	37.30	16.80	1.105	0.450
7	Henbery, medium-texture anatase	2.0	18.12	15.72	38.55	18.12	1.150	0.470
	Troilite	49.0	18.41	15.78	39.00	18.41	1.166	0.472
8	Tubil, edium-texture anatase	2.0	17.49	15.56	37.62	17.49	1.124	0.465
9	Santa Catarina, ataxite No. 2179	4.0	17.99	15.67	38.51	17.99	1.148	0.467
	Santa Catarina, ataxite No. 2180*							
	surface zone	2.4	16.42	14.44	35.04	16.42	1.137	0.469
	central zone	0.5	—	—	—	—	—	—
10	Boguslavka, hexahedrite	0.2	17.39	16.11	37.33	17.39	1.107	0.466
11	Gresk, hexahedrite	0.4	17.99	15.84	38.23	17.99	1.136	0.471
	Troilite	20.0	18.07	15.87	38.23	18.07	1.138	0.473
12	Chebankol, octahedrite coarse-textured	0.3	17.68	15.76	38.49	17.68	1.122	0.459
13	Chinge, ataxite	0.3	16.89	15.27	37.38	16.89	1.105	0.478
14	Sikhote-Alinskiy anatase coarse-textured, No. 2052	0.3	17.89	15.84	38.19	17.89	1.129	0.469
	" No. 1653	0.3	17.55	15.60	37.97	17.55	1.125	0.462
	Troilite	10.0	17.60	15.76	37.88	17.60	1.116	0.465

*The batch for the mass-spectrometric analysis amounted to $1 \cdot 10^{-6}$ g of lead and the percentage of Pb^{204} was, therefore, not determined accurately enough.

mpossible to maintain with absolute certainity hat the isotopic composition of lead separated rom the meteorites of the Devil's Canyon ype [7, 27] is actually primeval lead. Never-heless, in the first approximation one may ıssume this composition to represent primeval ead. Thus, in calculating the age of the earth, ıllowance may be made for primeval lead, out it is still necessary to find a terrestrial natter suitable for age determinations. An ıverage sample of the earth could serve as uch an ideal substance. Yet, such a sample s simply inconceivable, since all terrestrial natter is sharply differentiated. In calculating ıge on the basis of radioactive minerals, it is possible, as mentioned earlier, to determine the age only of that mineral which serves as the lower age limit of the earth.

Consequently, only the rocks as a whole, or the lead minerals separated from them would be suitable for these purposes. There can be no assurance in either case that the revealed content of primeval lead corresponds to the basic magma, since differentiation of the terrestrial matter has occurred many times in the history of the earth.

The most closely studied determination of the earth's age is based on isotopic lead separated

from galenas. In this case it is assumed that the lead from galena ores consists of primeval and radiogenic lead formed from the parent substance prior to the separation of lead as an independent mineral.

Calculations of the earth's age on the basis of galena are made with the understanding that the Pb/(U + Th) ratio in parent magma is constant in all cases. This supposition depends to a considerable extent on another hypothesis concerning the conditions of mineral lead formation. It appears that for the time being one should accept the viewpoint that mineral lead was formed directly from magma.

Most authors calculated the age by mathematical methods which do not require knowledge of the isotopic composition of primeval lead [2, 14, 20]. The most commonly used method of calculation at the present time is that of isochrons, but one should bear in mind here that its convenience of application does not preclude the necessity of observing the conditions under which it is operative. The basic condition to be considered in using the method of isochrons is that the Pb/U ratio in parent magma is the same everywhere and that the difference in isotopic compositions of mineral leads is determined only by the time of their separation. The earth's age may also be computed by another mathematical method; for example, by extrapolation of the lead isotopic composition in the earth's crust down to its original content. This method also requires that the isotopes Pb^{206} and Pb^{207} (in relation to Pb^{204}) at initial time t_0 should be evenly distributed throughout all of the terrestrial matter.

The ratio of lead isotopes could not be affected by the chemical and physical processes occurring in the earth. It could change only as a result of continuous accumulation of radiogenic lead. The differentiation processes in the earth may have caused fluctuations in the Pb/U and Pb/Th ratios in different parts of the earth. This may have lead to the fact that the isotopic composition of lead in coeval lead ores turned out to be different. Consequently, the interpretation of the data on the variation of the isotopic composition of lead with time in the earth's crust is very difficult. Table 2 shows the estimates of the earth's age made on the basis of the isotopic composition of mineral leads.

All of the resulting values range between 3.9 to 5.3 billion years. It should be noted that the table includes only the age values which exceed 3.5 billion years (the age of the most ancient sections of the continent). Each author interpreted his results differently. This matter, however, will not be discussed here since it is impossible to solve these questions at present.

In considering the values incorporated in Table 2 it is important to note first of all that the spread of the figures is not too great in relation to the age of the earth and may be attributed to: 1) insufficiently definite initial positions on the constancy of Pb/(U + Th) ratio in the magma and on the origin of lead ores; 2) difficulties encountered in determining the age of the investigated lead samples; 3) insufficient data analyzed by each author.

Attempts made by certain authors to more closely approximate the correct value of the earth's age by more precise mathematical computations failed to yield positive results, because the different methods of mathematical calculation differ one from another mainly in the convenience of the calculation itself. A more accurate age value can be obtained by

Table 2

The Age of the Earth According to the Isotopic Composition of Mineral Lead

Author	Year of determination	Age, billions of years	Remarks	
I. Ye. Starik	1937	5.0	Age of the Earth	
Kosci	1943	5.33	"	terrestrial matter
G. Jeffries	1948	4.0	"	Earth's crust
R. Alfar and R. Hermann	1951	5.3	"	Earth
A.P. Vinogradov, et al.	1953	4.9	"	Earth's crust
F. Houtermans	1953	4.5	"	" "
Heiss	1954	5.0	"	Earth
Farquhar	1956	3.9	"	"
A. Nier, Heiss, Farquhar	1956	4.1	"	"
F. Houtermans	1957	4.5	"	"

nore thorough sampling of galena ores and by itudying them thoroughly.

The earth's age determinations also may be ffected on the basis of a radiochemical analysis and the isotopic lead composition of ocks. The methods of the mathematical processing of experimental data are similar to hose used for mineral leads. In the case of ocks it is necessary to calculate the accumuation of radiogenic lead resulting from uranium nd thorium disintegration in the rocks throughut their lifetime. The age of the magma substance is determined on the basis of the calculated isotopic composition of primeval lead. f the differentiation of the earth occurred mmediately after its formation, then the age alues obtained for magma can be identified vith the age of the earth. Unfortunately, the lata are not sufficient at the present time for oetaneous rocks from different geologic reions to permit the calculation of time of the lifferentiation with appropriate approximation.

We shall dwell on the results of a determination of age relative to the magmatic chamer of the Terskey Ala-Tau. From the data ontained in Table 3 for ten varieties of granies one can establish the isotopic composition

Table 3

Uranium and Lead Contents and the Isotopic Composition of Lead in the Terskey Ala-Tau Granites

Sample	Contents in 10^{-6} g/g		Isotopic Composition of lead $Pb^{204} = 1$	Time t million years back	
	U	Pb		0	500
1102	12.06	22.0	206	21.16	18.02
			207	16.00	15.79
1103	12.9	28.0	206	20.36	17.87
			207	16.00	15.88
239	1.4	24.0	206	18.50	18.22
			207	15.92	15.91
276	2.9	71.0	206	17.89	17.69
			207	15.69	15.68
1106	11.4	26.0	206	20.85	18.48
			207	16.08	15.94

Sample	Contents in 10^{-6} g/g		Isotopic Composition of lead $Pb^{204} = 1$	Time t million years back	
	U	Pb		0	500
3050	14.3	20.0	206	20.18	16.23
			207	15.65	15.43
1100	23.2	24.0	206	22.45	17.17
			207	16.11	15.73
2813-a	4.0	22.0	206	19.51	18.56
173	3.5	39.0	206	19.35	18.91
			207	15.85	15.80
1108	12.3	38.0	206	19.97	18.26
			207	15.00	14.87

f lead which was a part of the matter of these granites 500 million years ago. If one assumes hat the magmatic chamber was differentiated rior to the separation of the granite matter, hen the isotopic composition of primeval lead n various granite samples also turns out to ary. The isochron equation calculated by the nethod of the least squares is as follows: y = 1.14 + 0.257 x. The coefficient 0.257 corresponds to the ratio of radiogenic isotopes Pb^{207}/Pb^{206} (the isotopic composition of primeval lead is assumed to be constant and, consequently, does not affect the slope of the isochrons) and corresponds to the age of 3.1 billion years. Adding the age of the granite matter (500 million years), the age of the magma substance appears to be equal to 3.6 billion years.

The main advantage in utilizing the data on rocks, as compared with calculations based on mineral leads, for these computations is that the rocks, as a rule, are less exposed to any secondary processes which alter the isotopic composition of lead contained in them. The principal shortcoming of this method of age calculation is the inadequate accuracy of analytical, uranium and lead determinations.

An estimation of the age of the earth can be made in still another way: on the basis of the data on the contents of A^{40} in the atmosphere and of K^{40} in the lithosphere. K. Chackett [15] has postulated that argon has penetrated the atmosphere in a period of time from time t_0 to t_1. Beginning with time t_1, the earth's crust has solidified so much that further argon penetration into the atmosphere became inappreciable. In utilizing B. Guettenberg's data on the content of potassium in the earth's crust and those of A. Nier on the abundance of K^{40} [25], and assuming the thickness of the earth's crust as $4 \cdot 10^6$ cm with an average density of $3 \cdot 8$ g/cm^2, K. Chackett was able to calculate t_0 for two age limit values (2 and 1 billion years). The limit age values for the atmosphere turned out to be equal to 3.5 and 3.1 billion years respectively. Similar calculations were made by other authors who used

slightly different values of A^{40} and K^{40} abundances and the assumed thickness of the earth's crust. The atmosphere's age values obtained were close to 4.5 billion years.

So far, these data represent all of the possibilities for estimating the age of the earth from studies of terrestrial matter.

DETERMINATION OF THE AGE OF METEORIC BODIES

The concept of the age of meteorites is related to the accepted theory of their origin, and the age values obtained by different methods must correspond to different moments in the history of the meteorites.

The history of the existence of meteorites, from their inception to the moment they land on the earth, could be very complicated. The formation of planetary bodies was accompanied by heating caused by physico-chemical processes and the decay of short-lived radioactive isotopes. Depending on the dimensions of the planetary bodies, their heating could proceed with greater or lesser intensity. Consequently, the differentiation of the component matter could occur at different times. Excess heat, it seems, was removed by the ejection of a portion of the incandescent matter or by total destruction of the body. Subsequently, from the products of ejection or destruction, new bodies may have formed in which differentiation processes could have been possible, etc. The earlier the separation of the metallic phase, the older the isotopic lead composition should be.

Thus, it is possible to visualize the following stages in the history of the existence of meteoric matter: 1) origination of the nuclei of elements; 2) formation of planetary bodies; 3) differentiation of matter; 4) cooling of the bodies; 5) disintegration of the parent bodies and formation of meteorites. All these stages should correspond to definite ages.

The time of element formation was estimated above on the basis of the varying abundance of K^{40} and the isotopic composition of uranium. It is also possible to determine the time interval between the origination of nuclei and the moment when the meteorites or their parent bodies cooled sufficiently to be able to retain noble gases. For this purpose, the method based on the decay of J^{129} ($1.7 \cdot 10^7$ years) into stable Xe^{129} was used. Since all, or almost all, Xe^{129} was lost by the time the planetary body solidified, and while a proportion of J^{129} was still volatile, the present-day content of Xe^{129} in meteorites may, to a certain extent, reflect the time elapsed between the formation of the nuclei and the total decomposition of J^{129}. For example, G. I. Nasserburg and K. Hayden [24] and J. Reynolds and J. Lipson [28] were able to determine for the Nuovo Laredo and Birdsley meteorites that they failed to retain radiogenic Xe^{129} during the first $4.1 \cdot 10^8$ and $4.7 \cdot 10^8$ years, respectively, following the formation of the nuclei. However, these data are very tentative. The authors themselves point to a possible experimental error and to inadequate substantiation of the theoretical hypotheses.

The formation time for planetary bodies must, apparently, range within 400 to 500 million years as having elapsed from the formation of the nuclei until the differentiation of matter in the parent bodies. The moment of melting and phase separation of parent bodies may be determined by the lead method — Pb^{207}/Pb^{206}.

G. Patterson [27] was the first to apply this method to five meteorite samples (achondrite, two chondrites, and two iron meteorites: Table 4).

On the assumption that all of these meteorites belong to the same group, and consequently were simultaneously formed from one and the same primeval substance, or from the same parent body, he plotted an isochron in Pb^{207}/Pb^{204} coordinates relative to Pb^{206}/Pb^{204}. In this manner the isotopic ratio of Pb^{207}/Pb^{206} was ascertained in the primeval lead, while the isochron slope corresponded to the age of the meteoric substance.

Later, I. Ye. Starik, M. M. Shats, and E. V. Sobotovich [6] obtained data on the content of uranium and lead and its isotopic composition in three chrondites and one achrondite. All of these data are incorporated in Table 4. Upon the construction of a Pb^{207}/Pb^{204} graph in relation to Pb^{206}/Pb^{204}, all meteoric leads (with the exception of that from Norton County) were found to be located on a single straight line (isochron), the slope of which corresponds to the age of 4.45 ± 0.05 billion years.

R. Marshall [22] has shown that two chondrites investigated by him (Holbrook and Richardton, Table 4) also fall on this same straight line. The isochron equation calculated by the method of the least squares for all investigated stony meteorites (seven chondrites and two achondrites) has the form of $y = 4.7 + 0.60\,x$, where the coefficient 0.60 represents the ratio of radiogenic isotopes Pb^{207}/Pb^{206} and corresponds to the age of the meteoric matter of 4.5 billion years.

Table 4 contains the age values for stony meteorites calculated on the basis of ratios Pb^{206}/U^{238}, Pb^{207}/U^{235}, and Pb^{207}/Pb^{206}. A correction for the isotopic composition of primeval lead was introduced on the basis of the data on the isotopic composition of lead contained in the iron meteorite from Devil's Canyon.

Table 4

Age of Stony Meteorites

Name of Meteorite	Isotopic composition of lead $Pb^{204} = 1$			Age, billion years		
	206	207	208	$\frac{Pb^{206}}{U^{238}}$	$\frac{Pb^{207}}{U^{235}}$	$\frac{Pb^{207}}{U^{206}}$
Nuovo Laredo	50.28	34.86	67.97	6.3	5.1	4.4
Forest City	19.27	15.95	39.05	10	6.2	4.3
Modock	19.48	15.76	38.21	10	7.0	4.3
Saratov	19.58	16.70	40.25	3.2	4.1	4.5
Kunashak	19.64	16.24	40.04	3.8	4.3	4.4
Yelenovka	21.54	16.94	39.86	3.3	4.2	4.5
Norton County	22.75	15.87	37.70	4.5	4.2	3.9
Richardton	25.57	22.13	48.51	—	—	4.5
Holbrook	17.52	15.52	88.93	—	—	4.5

The age values of the Nuovo Laredo, Forest City, and Modok meteorites were computed from the data produced by G. Patterson [27] and H. Hamagushi, and others [18]. The age of the Forest City and Modok chondrites, calculated from the ratios Pb^{206}/U^{238} and Pb^{207}/U^{235}, are anomalously high. The Nuovo Laredo achondrite also shows a higher age value than one might have expected. This discrepancy can be explained either by an error in the analytical determination of the uranium, or by the fact that the authors used different samples of the same meteorite in their analyses.

It is possible that our present ideas about the origin and development of meteorites are not entirely correct. In certain cases the discrepancies in the age values can be attributed to the fact that analyses of uranium and lead were run for different samples of meteorites in which the content of these elements varied. Uranium and lead determinations and the mass-isotopic analysis of lead in the chondrites from Saratov, Yelenovka, Kunashak, and the Norton County achondrite were made on the same samples [8]. The somewhat lower age calculated on the basis of Pb^{207}/U^{235}, and particularly of Pb^{206}/U^{238}, therefore, may be, in this case, associated only with an error in the determination of uranium or lead, or with a loss in lead addition of uranium during the life of the meteorites.

For the Pasamonte achondrite the age value was obtained by the strontium method and amounts to 4. 54 billion years [30].

Thus, it is possible to consider the age of meteoritic matter as established, or the moment of melting and differentiation of the parent body of meteorites as 4. 5 billion years.

COOLING OF THE BODY

The moments when heating terminated are being estimated by helium and argon methods. The ages determined by these methods have a tendency to be somewhat lower than those obtained by the lead and strontium methods. This, apparently, is attributable to losses of helium and argon by diffusion, since the cooling of meteorites after their formation must have occurred quite rapidly. The spread of age figures by the argon method may be caused by size variations of the parent body and the location in it of the future meteorite samples. The discrepancies between the helium and argon ages could be explained by the difference in the diffusion coefficients of both gases.

Data obtained by the helium and argon methods for a number of stony meteorites show a maximum age value of approximately 4. 5 billion years. The acquisition of values indicating a younger age may be related to a number of circumstances, among which an important role may be played both by experimental errors, and by difficulties associated with the identification of the processes which may have affected the meteorites. For example, H. Urey [32] and F. Paneth [26] ascribed the lower age values of meteorites produced by the helium method to losses in helium which may have occurred during the heating of meteorites when the trajectory of their flight passed in the vicinity of the sun.

The age was calculated on the basis of the data for uranium content obtained by H. Hamagushi, and others, using the helium method [18], namely, of 10^{-8} g/g. Investigations by I. Ye. Starik and M. M. Shats [5] showed that the uranium content in stony meteorites varies within the limits of $1 \cdot 10^{-7}$ g/g. If this estimate is

correct, then the age determined by the helium method will appear to be lower by one order.

The age determined by the argon method of various stony meteorites also varies over a wide range of from 0. 7 to 4. 5 billion years. This fact is to be, apparently, attributed to argon losses. Nonetheless, it should be noted that age values determined by the argon method are far more stable than those produced by the helium method, and some of them are close to the upper age limit of meteorites (4. 2 to 4. 5 billion years).

One of the reasons responsible for the discrepancies in meteorite age determinations by the helium and argon methods also may be traced to the formation of other isotopes of these gases under the influence of cosmic radiation. This problem lately has become the subject of intensive studies.

THE COSMIC AGE OF METEORITES, THE TIME OF DISINTEGRATION OF THE PARENT BODY

Back in 1947 and 1948, C. Bauer [10, 11] and H. Hantley [21] succeeded in demonstrating experimentally the existence of He^3 and He^4 produced as a result of cosmic ray action upon meteoric bodies.

This discovery permitted a correction to be introduced in the calculations of the meteorite age by helium method for "cosmic" helium and to recalculate more accurately the previously obtained data. On the other hand, the products discovered in meteorites of "evaporation" and "calcination" of the atomic nuclei under the influence of cosmic high-energy particles make it possible to determine the, so-called, cosmic age of meteorites. The "cosmic age" is understood to mean the time during which the meteoric body was exposed to the action of cosmic rays in interplanetary space. The cosmic age of meteorites is calculated from the moment of disintegration of the parent body, i. e., from the moment when the meteorite begins an independent existence not shielded by the protective action of the mass which used to surround it, until the moment when it lands on the surface of the earth.

The constancy of the cosmic-ray flux in time and space, as well as the constancy of the parent body in shape and size, serve as the starting point for cosmic age calculations.

At the present time cosmic-age determinations of meteorites are based both on the number of any unit-element nuclei formed, for example, He^3, and on the pairs of different isotopes: H^3-He^3, K^{40}-K^{51}, A^{39}-K^{39}, A^{39}-Sr^{46}, A^{39}-A^{38}. It should be noted, that in the case of unit elements, the available data are somewhat indefinite because the intensity of cosmic rays in space until recently was unknown, and it was only since the launching of the sputnik that our knowledge has been enriched by the necessary information. In this connection there were some difficulties with respect to calculations of secondary-radiation effects.

Determination of meteorite age on the basis of various isotopic pairs, on the other hand, does not require certain knowledge of the energy spectrum of the emerging particles in so far as this concerns the reaction products, the effective cross-section of which is approximately constant in this energy range. In this case the size of the meteoric body is of no consequence.

As may be seen from Table 5 which shows the results of the latest research in the field of cosmic-age determinations of meteorites based on the isotopic pairs, the age of iron meteorites

Table 5

The Cosmic Age of Meteorites

Sample designation	Class of meteorite	Method of determination	Age, billion years	Author
Abiya	Stony chondrite	He^3—H^3	13	F. Begemann [12]
Norton County	" "	He^3—H^3	240 280	" [13]
Sikhote-Alin'	Iron	He^3—H^3	900±200	E.K. Gerling [3] L.K. Levskiy [3]
"	"	K^{39}—A^{39}	430±50	E. Firemann [16]
"	"	A^{38}—A^{39}	500	R. Marshall [22]
Carbo	"	K^{41}—K^{40}	690	H. Wänke, E. Vilasek [33]
Treisa	"	A^{39}—Sr^{46}	600	E. Firemann D. Schwarzer [17]
Norfolk	"	He —H^3	900	
Cara de Minas	"	He^3—H^3	1700	

varies over the range of $1 \cdot 700 \cdot 10^6$ to $430 \cdot 10^6$ years.

It is necessary to note that O. Schaeffer and J. Zaehringer in their study [29], devoted to the rate of He^3-H^3 formation under the action of protons on targets prepared from meteoric iron, have shown that the age of iron meteorites determined by He^3-H^3 may appear to be about three times higher than it actually is.

The cosmic age of stony meteorites is much lower than that of the iron variety. However, this phenomenon has not yet been conclusively explained. The low age of the Abiya chondrite is attributed by F. Begemann and others [12] to the fact that 13 million years ago this meteorite possibly may have been a part of a large meteor and was protected by the shielding effect of the ambient medium, whereupon the meteor had split up without noticeable heating. A gradual loss of mass, or repeated processes of cleavage of small fragments also may be used as another possible explanation of the phenomenon. In this case the intensity of cosmic radiation affecting the body formed as a result of cleavage will increase.

* * *

As previously indicated, the problem of the age of the earth is related to ideas concerning its origin and development.

In order to extend the age values obtained for meteorites to the earth, it is necessary to have the assurance that: 1) the parent bodies of the meteorites and the earth were formed at identical times and existed as isolated systems; 2) the isotopic composition of lead, uranium, and thorium in the meteoric matter and the matter of the earth was originally identical. In the first approximation, this condition seems to be holding for all bodies of the solar system if the formation of heavy elements occurred within a relatively short period of time.

Thus, if it were possible to prove that meteoric and terrestrial matter have a common origin, then the experimentally determined age of the planetary bodies justifiably could be related to the age of the earth. In this case, the isotopic compositions of averaged terrestrial lead and the lead from meteorites should satisfy the following equations derived by G. Patterson [27]:

$$Pb^{206}/Pb^{204} = 9.5 + 1 \cdot 014\ U^{238}/Pb^{204}$$

$$Pb^{207}/Pb^{204} = 10.4 \pm 0 \cdot 601\ U^{238}/Pb^{204}$$

Indeed, these expressions are satisfied both by the meteoric lead and by that of terrestrial origin separated from recent oceanic sediments, as well as by the averaged lead from Tertiary and Quaternary galenites.

This fact may serve as an argument in favor of the advanced supposition.

Utilized in this expression are the isotopic ratios $Pb^{206}/Pb^{204} = 9.5$ and $Pb^{207}/Pb^{204} = 10.4$ obtained for the iron meteorite in Devil's Canyon which serve as a measure of terrestrial and meteoric primeval lead. However, there are data relative to iron meteorites (Table 1) in which the isotopic lead composition differs considerably from primeval lead. Their age and origin are, therefore, different from those of the Devil's Canyon meteorite and, possibly, also from those of a number of stony meteorites.

Since two groups of iron meteorites, sharply differing in terms of isotopic lead composition, were discovered (Table 1), it is difficult to imagine how such differentiation could occur in a single molten metallic phase. One cannot help but assume that there can be, not one, but a number of parent bodies of meteorites, in which the differentiation processes developed at different times, with the isotopic lead composition reflecting the time of the last differentiation. Thus, in the case of the first-group meteorites (containing primeval isotopic lead composition), the separation of the metallic phase took place 4.5 billion years ago, while in the case of the second group of meteorites, (having regular isotopic lead composition), this separation may be estimated to have lasted several tens (or a hundred) millions of years. In the case of the Sikhote-Alin' meteorite, one can observe a coincidence of the "cosmic age" (400 to 500 million years) and the time of the last differentiation of the body (the isotopic composition of lead in the Sikhote-Alin' meteorite corresponds to ordinary terrestrial lead, 400 to 500 million years old). If these figures are correct, one must assume that the parent body from which the Sikhote-Alin' meteorite originated must have disintegrated immediately after differentiation in it ceased.

The possibility should not be excluded that there also may be other processes which could serve as a basis for the explanation of the presence of lead with different isotopic compositions in iron meteorites.

For the majority of the investigated meteorites, the age values for the parent substance obtained by the lead, strontium, and argon methods, are close to those of terrestrial matter.

The results of age determinations with respect to the earth obtained by all possible radioactive methods show that the age of the earth is 3.5 to 5.0 billion years, with the most probable figure being that of 4.5 billion years.

REFERENCES

1. Baranov, V.I., Radiometriya. [RADIOMETRY]: Izd-vo Akad. Nauk SSSR, 1955.

2. Vinogradov, A.P., I.K. Zadorozhnyy, and S.I. Zykov, Izotopnyy sostav svintsov i vozrast Zemli. [THE ISOTOPIC COMPOSITION OF LEADS AND THE AGE OF THE EARTH]: Doklady, Akad. Nauk SSSR, t. 85, no. 5, 1952.

3. Gerling, E.K., and L.K. Levskiy, Kosmicheskiy vozrast Sikhote-Alinskogo meteoritakh. [THE COSMIC AGE OF THE SIKHOTE-ALIN' METEORITE]: Geokhimiya, no. 2, 1956.

4. Gerling, E.K., K voprosu o vosraste Zemli po radioaktivnym dannym. [THE PROBLEM OF THE AGE OF THE EARTH ACCORDING TO RADIOACTIVE DATA]: Doklady, Akad. Nauk SSSR, t. 34, no. 9, 1942.

5. Starik, I. Ye., and M.M. Shats, Opredeleniye urana v kamennykh i zheleznykh meteoritakh. [URANIUM DETERMINATION IN STONY AND IRON METEORITES]: Geokhimiya, no. 2, 1956.

6. Starik, I. Ye., M.M. Shats, and E.V. Sobotovich, O vozraste meteoritov. [THE AGE OF METEORITES]: Doklady, Akad. Nauk SSSR, t. 123, no. 3, 1958.

7. Starik, I. Ye., E.V. Sobotovich, G.P. Lovtsyus, M.M. Shats, and A.V. Lovtsyus, Opredeleniye soderzhaniya svintsa i yego izotopnogo sostave v zheleznykh meteoritakh. [DETERMINATION OF THE CONTENT OF LEAD AND ITS ISOTOPIC COMPOSITION IN IRON METEORITES]: Radiokhimiya, t. 1, vyp. 5, 1959.

8. Starik, I. Ye., E.V. Sobotovich, G.P. Lovtsyus, M.M. Shats, and A.V. Lovtsyus, Svinets i yego izotopnyy sostav v zheleznykh meteoritakh. [LEAD AND ITS ISOTOPIC COMPOSITION IN IRON METEORITES]: Doklady, Akad. Nauk SSSR, t. 134, no. 3, 1960.

9. Cherdyntsev, V.V., Rasprostraneniye khimicheskikh elementov. [THE DISTRIBUTION OF CHEMICAL ELEMENTS]: Gostekhizdat, 1956.

10. Bauer, C.A., Production of helium in meteorites by cosmic radiation. Phys. Rev., vol. 72, no. 8, 1947.

11. Bauer, C.A., The absorption of cosmic radiation in meteorites. Phys. Rev., vol. 74, no. 2, 1948.

12. Begemann, F., I. Geiss, and D.C. Hess, Radiation age of a meteorite from cosmic-ray-produced He^3 and H^3. Phys. Rev., vol. 107, no. 2, 1957.

13. Begemann, F., P. Eberhardt, and D.C. Hess, Z. Naturforsch. a, Bd. 14a, 1959.

14. Bullard, E.C., and J.P. Stanley, The age of the earth. Veröff. Finn. Geodät. Inst., no. 36, 1949.

15. Chackett, K.F., K^{40} and the age of the atmosphere. Phys. Rev., vol. 81, no. 6, 1951.

16. Firemann, E.L., Tritium production by 2.2-Feb protons on Fe and its relation to cosmic radiation. Phys. Rev., vol. 97, no. 5, 1955.

17. Firemanng, E.L., and D. Schwarzer, Measurement of Li^6, He^3 and H^3 in meteorites and its relation to cosmic radiation. Geochim. cosmochim. acta, vol. 11, no. 4, 1957.

18. Hamagushi, H., G.W. Reed, and A. Turkevich, Uranium and barium in stone meteorites. Geochim., cosmochim. acta, vol. 12, no. 4, 1957.

19. Houtermans, F.C., Radioaktivität und Alter der Erde. Naturwissenschaften, H. 6, 1957.

20. Houtermans, F.C., Z. Naturforsch. a, Bd. 2a, S. 322, 1947.

21. Hantley, H.E., Production of helium by cosmic rays. Nature, vol. 161, no. 4087, 1948.

22. Marshall, R.R., Calculation of a "Cosmic Ray Age" for the iron meteorite "carbo". Nature, vol. 184, no. 4680, 1959.

23. Meyer, S., Über das "Alter" der Sonne, über die Zerfallskonstante des Actinurans und über das Mangenverhältnis Blei zu Uran auf der Erde. Naturwiss. Hf. 47, 1937.

24. Nasserburg, G.I., and K.I. Hagden, Geochim. cosmochim. acta, vol. 12, no. 4, 1957.

25. Nier, A.O., Redetermination of the relative abundances of the isotopes of carbon, nitrogen, oxygen, argon, and potassium. Geochim. cosmochim. acta, vol. 7, no. 1/2, 1955.

26. Paneth, F.D., Recent studies of iron meteorites. I. Introduction. Geochim. cosmochim. acta, vol. 3, no. 6, 1953.

27. Patterson, C., Age of meteorites and the earth. Geochim. cosmochim. acta, vol. 10, no. 4, 1956.

28. Reynolds, J. H., and J. I. Lipson, Geochim. cosmochim. acta, vol. 12, no. 4, 1957.

29. Schaeffer, O. A., and J. Zähringer, High sensitivity mass spectrometric measurement of stable He and A isotopes produced by high-energy protons in Fe. Phys. Rev., vol. 113, 1959.

30. Schumacher, E., Altersbestimmung von Steinmeteoriten mit der Rubidium — Strontium — Methode. Z. Naturforsch. a, Bd. 11-a. H. 3, 1956.

31. Suss, H. E., and H. C. Yrey, Rev. Mod. Phys., vol. 28, 1956.

32. Urey, H. C., The origin and development of the earth and other terrestrial planets. Geochim. cosmochim. acta, vol. 1, no. 4, 1951.

33. Wänke, H., and E. Vilasek, Z. Naturforsch. Bd. 14a, H. 11, 1959.

The Radium Institute of the
U. S. S. R. Academy of Sciences,
Leningrad

Received, 1 November 1960

MESOZOIC VOLCANISM IN NORTHEAST YAKUTIYA[1]

by

I. Ya. Nekrasov

On the basis of many years of the author's personal observations and the materials collected during the last three years by the collective geologists of the Yakutiya Administration, the development pattern of Mesozoic volcanism is presented for the first time, certain regularities in the formation of volcanic strata and subvolcanic intrusions are elucidated and an estimate is given as to their metal content.

* * * * *

The principal structural features in Northeastern Yakutiya are the Kolyma central massif and the Verkhoyansk-Kolyma folded zone [5, 8]. A deep-seated fault separates the Verkhoyansk-Kolyma folded zone from the central massif (Figure 1). Throughout the Upper Jurassic and Cretaceous periods this fault controlled the volcanic activity in the Verkhoyansk-Kolyma folded zone and the marginal geanticlines (Poluosniy and Tas-Khayaktakh) of the Kolyma central massif.

The duration and intensity of the volcanic activity, the petrographic composition and the metal content of the volcanic formations in the Kolyma central massif and the Verkhoyansk-Kolyma folded zone vary. Throughout the entire Mesozoic period the Kolyma central massif experienced repeated block movements along the long-lived deep faults which served as magma conduits. As a result of long and intensive volcanic activity continuing through the entire Mesozoic period, a thick (7 to 7.5 km) series of sedimentary-volcanic and volcanic rocks was formed here. The most mobile part of the Kolyma central massif was the region of the central Alazeysk uplift, within which the marine sedimentary-volcanic (Triassic-Jurassic) formations, the volcanic formations of the surface type formed during Cretaceous and Paleogene time, and the accompanying subvolcanic intrusive rocks, were extensively developed. The quiet outflow of lava in the Alazeysk uplift alternated with recurrent explosions which were responsible for the fact that 50% of the sedimentary-volcanic formations consist of pyroclastic formations [9]. Characteristic for the Verkhoyansk-Kolyma folded zone is the abundance of Lower and Upper Cretaceous, occasionally Paleogene, effusives and sub-volcanic intrusions, and a very negligible amount of pyroclastics. The accumulation of volcanic strata occurred here exclusively under subaerial conditions in the period subsequent to folding.

Five main stages of volcanic activity, separated by intervals of varying lengths, can be identified in the Kolyma central massif (Table 1). Characteristic of the volcanic formations in the Verkhoyansk-Kolyma folded zone are only three stages of Mesozoic volcanism (Table 2), synchronous with the three last stages of volcanic activity in the Kolyma central massif.

1. VOLCANISM IN THE KOLYMA MEDIAN MASS

The peculiarity of the volcanism in the Kolyma central massif is the protracted formative process of the sedimentary-volcanic deposits (extending from the Permian to the Paleogene). Of the total thickness of the sedimentary-volcanic strata amounting to 7000 to 7500 m, about 6500 m were formed under the conditions of a marine basin (in the two first stages), and only 800 to 1000 m are lavas of the surface type.

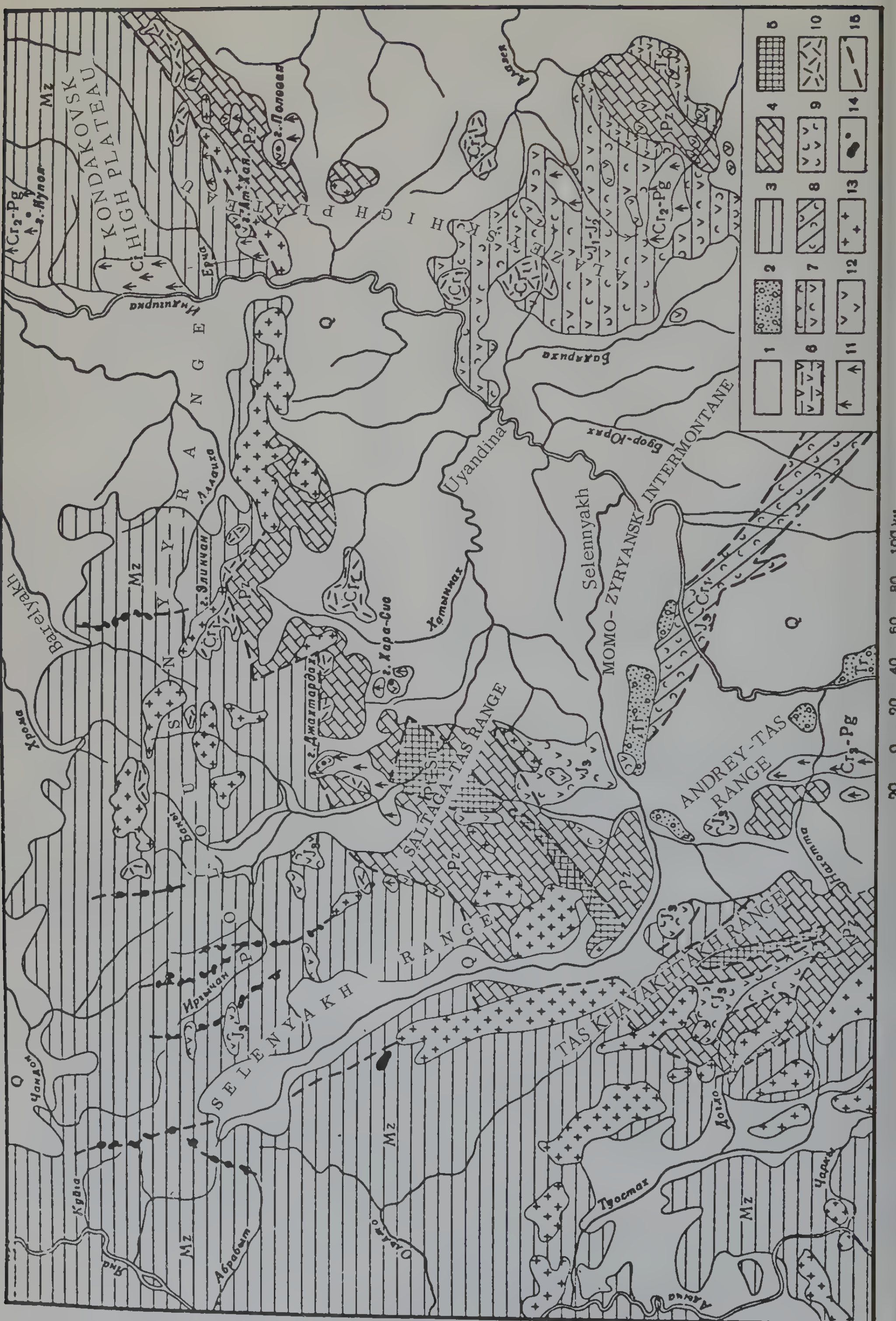
In the first stage of volcanism (Triassic period) a sedimentary-volcanic formation, 300 to 1000 m in thickness, was formed in the Alazeysk uplift of the Kolyma central massif. About 85% of the rocks here are andesites, agglomerates, litho-, and crystalline-clastic tuffs of andesites and andesitic basalts, and about 10% of the litho-clastic tuffs are of

[1] O mezozoyskom vulkanizme severo-vostochnoy Yakutii, (pp. 84-96).

Table 1

The Development Pattern of Mesozoic Volcanism in the Territory of the Kolyma Central Massif

Age of volcanism	Volcanic formations			Subvolcanic Intrusions			Volcanic activity zones
	Petrographic composition	Mode of occurrence	Chief metallogenic elements	Petrographic composition	Mode of occurrence	Chief metallogenic elements	
Upper Cretaceous-Paleogene	Liparites, trachytes, occasional tuffs	Flows, volcanic vents	Sn, Ce, Y Li, Hg	Granite-porphyries, syenite-porphyries	Stocks, dikes	Sn, Li. Be, Ce, Y, Zr, Hg	Alazeysk high plateau Andrey-Tass Range
Lower Cretaceous	Andesites, and their tuffs	Flows	Ti, TR, Hg	Diroitic porphyrites, monzonites, diorites, and rarely syenites	Necks, dikes	Co, As, Cu, Zn, TR, Ti, Hg	Momo-Zyryansk, Syuryuktyakh basin, Tas-Khayaktakh and Polousnyy Ranges
Upper Jurassic	Andesites in marginal anticlinoria, liparites, dacites and their tuffs in Alazeysk uplift	Flows with total thickness of 2000-2500 m	Cu, Hg	Gabbro-diabases, dioritic porphyrites, diorites, granite-porphyries, and granodiorite-porphyries	Stocks, dikes, stills	Cu, Zn, Pb, As, Hg, Au	Polousnyy, Ulakhan-Sis, Tas-Khayakh-Ranges, Selennykh Ridge, Alazeysk high plateau
Lower and Middle Jurasic	Andesites and their tuffs, subordinate role: basalts, liparites, and their tuffs	Flows in the sedimentary volcanic series; 3500-3800 m thick	V, Ti	Diorites, dioritic porphyrites, rarely granite-porphyries, quartz porphyries, granodiorite porphyries	Necks, stocks, dikes, sills, and volcanic pipes	V, Ti, Ni, Co, Cu, Sn	Alazeysk high plateau
Triassic	Agglomerates, ash, crystallo-clastic tuffs of andesites, andesite-basalts, tuffites	Flows in the sedimentary-volcanic series, 700 m thick	—	Andesites and basalts	Dikes and sills	V, Ti, Ni, Co	Alazeysk high plateau (Sededema River basin)


KONDAKOVSK HIGH PLATEAU
P O L O U S N Y Y R A N G E
SELENYAKH RANGE
SALTAGA-TAS RANGE
MOMO-ZYRYANSK INTERMONTANE
ANDREY-TAS RANGE
TAS KHAYAKHTAKH RANGE
Uyandina
Selennyakh
Mz
Q
0 20 40 60 80 100 км

dacitic composition. About 5% of the total thickness of this formation consists of tufogenic sandstones and shales located in the upper section and containing abundant Triassic fauna. The alternation of effusive-pyroclastic formations with normal sedimentary rocks is evidence of the fact that during the Triassic, the central part of the Alazeysk uplift was, apparently, an archipelago, which consisted of a number of islands of volcanic origin. The considerable thickness of the deposits of volcanic origin and the non-uniform thickness of the individual beds of effusives and tuffs, — which vary sharply over short distances of 2 to 3 km — indicates the existence of a number of eruption centers of the strato-volcanic type. These strato-volcanic centers were located in the northeastern zone of weakness which coincides with the axial section of the Alazeysk horst-anticline.

The rocks of the effusives here are represented by the dikes and sills of dipyroxene basalts which are poorly developed in the Sededema River basin. The dikes and sills do not exceed 5 m in thickness and their length varies between 300 and 800 m. The andesites and basalts are strongly altered (chloritization and carbonatization). According to the data of chemical and spectral analyses they contain up to 4.5-5% titanium oxide (dispersed finely impregnated titanomagnetite) and up to 0.05% zinc; hundredths, thousandths, and ten-thousandths fractions of one percent of vanadium, chrome, nickel and copper.

The <u>second stage of volcanic activity</u>, embracing the period from the Triassic to the Upper Jurassic, was manifested — like the first stage — only in the Alazeysk uplift of the Kolyma central massif. Two cycles of volcanic activity may be distinctly identified: the Lower and the Middle Jurassic, separated in time by a negligible hiatus determinable by the existence of a bed of basaltic conglomerates. The sedimentary-volcanic formations of both cycles are characterized by fauna.

The initial stage of the Lower Jurassic volcanic cycle saw the outflow of average -composition lavas responsible for the formation of sedimentary-volcanic strata about 700 m thick. The bottom of this formation consists of olivine basalts and pyroxene andesites, and at the top, of ash and agglomeratic tuffs containing interbedded tufogenic limestones and shales. Spectral analysis showed that the andesites and basalts in this volcanic formation contain high concentrations of vanadium, titanium, chrome, and to a lesser extent, cobalt and copper. Although the percentages of these elements are negligible, they nevertheless exceed the Clarke values by a factor of two or three.

The second stage of the Lower Jurassic volcanic cycle was marked by the extrusion of

FIGURE 1. Sketch map of the geologic structure of the northeastern part of Yakutiya (compiled by I.Ya. Yekrasov)

1 - Quaternary deposits (silts, loams, peats, pebble beds, etc.); 2 - Tertiary conglomerates and sandstones; 3 - Mesozoic (Triassic and Jurassic) schistose sandstone formation; Paleozoic (Ordovician, Silurian, Devonian, and Carboniferous) carbonate formation; 5 - crystalline Proterozoic and Sinian formation (amphibolites, gneisses, crystalline schists); 6 - Triassic volcanic-sedimentary formation of the Alazeysk high plateau; 7 - Lower and Middle Jurassic sedimentary-volcanic formation of the Alazeysk high plateau; 8 - Upper Jurassic - Lower Cretaceous volcanic-sedimentary coal measures of the Momo-Zyryansk intermontane basin; 9 - Upper Jurassic volcanic and sedimentary-volcanic formation of the superimposed basins (Dogdinskaya and Saltaga-Tasskaya) of the Kolyma central massif, and of the western part of the Poluosnyy Range; 10 - Lower Cretaceous effusives; 11 - Upper Cretaceous-Paleogene effusives; 12 - main sub-volcanic intrusives; 13 - Upper Jurassic - Lower Cretaceous granitoids in the batholith-like masses; 14 - Upper Cretaceous granitoids - very basic; 15 - the principal deep-seated faults

Table 2

The Development Pattern of Mesozoic Volcanism in the Territory of the Western Part of the Verkhoyansk-Kolyma Folded Zone

Age of volcanism	Volcanic formations			Subvolcanic Intrusions			Volcanic activity zones
	Petrographic composition	Mode of occurrence	Chief metallogenic elements	Petrographic composition	Mode of occurrence	Chief metallogenic elements	
Upper Cretaceous — Paleogene	Andesites, basalts, tuffs, welded tuffs, volcanic bomb horizons	Flows, volcanic vents	Ti, As, Co, Ni, Hg	Diroritic porphyrites, granodiorite-porphyries, diorites, monzonites, syenites	Dikes, and necks	Ti, Mo, Co, Ni, As, TR, Hg	Kondakovsk high plateau, Dzhakhtardakh Mountains in the Polousnyy Range Ulakhan-Sis Range
Upper Jurassic — Lower Cretaceous	Liparites, dacites, liparitic dacites	Flows	Sn, Be, Li, B	Granite-porphyries, granodiorite-porphyries, quartz-porphyries	Stocks, dikes, sills	Sn, Mo, W, Be, B, Li, As, U, Pb	Polousnyy, Tas-Khayakhtakh, and Ulakhan-Sis Ranges
End of Upper Jurassic	Andesites, dacites, liparites, very rarely tuffs	Flows in schistose sandstone formation	As, Co, Cu, Hg	Gabbro-diabases, granite-porphyries, quartz porphyries	Sills and dikes	Hg, Co, Cu, As, Mo, Sn, Be	Western part of the Polousnyy Range

excessively acid lavas (liparites, occasional dacites). The 900 meter tufogenic liparite formation contains up to 30% pyroclastics (tuffs an[d] tuffites of liparites and dacites). The products of the extruded acid lava, particularly the liparites, are hydrothermally altered (sulfidization, sericitization), intensely porous and honeycombed. Spectral and chemical analyses show that the liparites contain high concentrations of barium, strontium, lithium, zinc, lead, and copper, exceeding by 3 to 6 times the Clarkes of these elements in the earth's crust. The final stage of the Lower Jurassic volcanic cycle is well characterized by the increased role played by pyroclastic rocks represented by litho-crystallo-clastic, crystallo-clastic and, agglomeratic tuffs of the andesites. Tuffites are very poorly developed in this formation and there are no effusives. A sedimentary-volcanic formation aggregating 800 m was formed during this stage.

The Middle Jurassic volcanic cycle was ushered in by the outflow of average-composition lavas (andesites and dacites), and then by basic lavas (amygdaloidal basalts). Pyroclastic rocks, represented by agglomeratic and ash tuffs and tuffites, are well developed in the Middle Jurassic sedimentary-volcanic strata, on the order of 1000 to 1100 m in thickness. The agglomeratic tuffs occur only near the lava cones. They have a uniform thickness and wedging out sharply 2 to 4 km from the centers of volcanic activity. The ash tuffs form uniformly thick beds extending out 5 to 8 km, but their development is local. All of this justifies the assumption that, apart from linear fissure-type vents, numerous volcanoes of the central type also existed in Middle Jurassic time.

Volcanic activity during the second stage was controlled mainly by linear faults of northeasterly strike which, probably, abounded in volcanic systems of the strato-cone type. A thick (3500 to 3800 m) sedimentary-volcanic formation, consisting mostly of pyroclastic rocks, formed along these faults.

The subvolcanic intrusions, which accompanied the volcanic activity in the second stage, are represented by steeply dipping sills, dikes, and stocks of diorites, quartz-diorites and dioritic porphyrites (in the basins of the Kopylyn-Chekur, Ebir-Khaya, Yngyr-Khaya Rivers and others). It is very strange that, along with subvolcanic stock-like intrusions, there also exist typical interbedded intrusions, similar to those of trappean formation observable on the Siberian platform. The diorites and dioritic porphyrites, as well as certain tuffs and andesites located near the intrusions are enriched with ilmenite and magnetite to the extent of forming orebodies of commercial importance. Orebodies containing impregnated magnetite and ilmenite are localized within the limits of the linearly-extended zones of weakness and occur as schlieren and thin lenses (0.1 to 0.2 m). They constitute the basic

source for the formation of numerous alluvial placers of ilmenite and magnetite in the central part of the Alazeysk high plateau. In 1954 I. P. Shlykov and I. N. Karbivnich described the ilmenite- and garnet-bearing tuffs which outwardly resemble the volcanic pipes characteristic of the Siberian platform.

The beginning of the third volcanic activity stage coincided with the intensive fold-forming movements to which the Paleozoic basement of the Kolyma central massif reacted by block uplifts. The Kolyma fracture, formed at the juncture of two formations of different age (the Mesozoic terrigenous and the Paleozoic carbonaceous strata) is the main structural fracture zone controlling the volcanic activity in the Upper Jurassic and Lower Cretaceous periods. Less important deep faults originated in the central part of the Kolyma central massif and separated the intermontane basins (Momo-Zyryansk, Dogdinsk, Chabagylakh, Saltaga-Tas, and others). These intermontane troughs are filled with sedimentary-volcanic and volcanic deposits. The Upper Jurassic age of the volcanic formations is everywhere characterized by the presence of abundant fauna in the shales, sandstones and tuffs which alternate with the effusives.

The volcanic rocks formed as a result of lava flows issuing from these newly-developed deep-seated faults (in the Selennykh Ridge, in the Tas-Khayakhtakh and Polousnyy Ranges) are distinctly different from the volcanic rocks formed as the result of the partial reopening of the previously existing magma-conduits in the central part of the Alazeysk plateau. These distinctions may be summed up as follows.

1. Near the young (Upper Jurassic ?) deep-seated faults in the zone of the marginal geanticlines of the Kolyma central massifs, the pyroclastic rocks are totally absent, but within the limits of the long-standing superimposed faults of the Alazeysk uplift they are well developed.

2. The lavas which flowed along the youthful faults were essentially average in composition (andesites and dacites), and those which moved along the partially reopened conduits were mostly acidic (liparites, dacites, and their tuffs). This difference in the composition of the lava flows may be due to the varying depths of the centers of volcanic activity. The largest faults (for example, the main Kolyma faults) may have extended to great depths and controlled the extrusion of average, rarely basic, lavas from the poorly differentiated magmatic chambers. The smaller, near-surface faults on the Alazeysk uplift could have reached only the more differentiated chambers containing a magma of acid composition.

The third-stage volcanism was terminated with the formation of minor subvolcanic intrusions. In the main Kolyma fault zone many stocks, dikes, and sills of gabbro-diabases, diorites, and diorite-porphyrites (Yelenekh, Khatynnakh-Salinsk, Dogdinsk, etc.) were formed, whereas only extended dike bodies of granite-porphyries, quartz-porphyries, and grano-diorite-porphyries appeared during the Alazeysk uplift.

Under the influence of postmagmatic solutions the effusives and subvolcanic intrusive rocks were strongly altered in a number of places (albitized, silicified, chloritized, and sulfidized). According to the data of this author, V. K. Pokrovskiy, and I. P. Shlykov, the auriferous mineralization in the Iolatakh and Khatynnakh-Salinsk group of ore showings is paragenetically associated with the albitized and sulfidized dikes of the dioritic porphyrites and diabases of the Selennyakh Ridge. The mercury mineralization of the quartz-baritic formation is associated with the Upper Jurassic effusives in the Dogdinsk intermontane trough (Tas-Khayakhtakh Range, while the effusive rocks of the Saltaga-Tas Range are related to the thick zones of pyrite ores (pyrite, marcasite, arsenopyrite, chalcopyrite, and occasionally sphalerite).

For the volcanic formations in the Alazeysk uplift spectral analyses show high values of lead, zinc, tin, barium, lithium, rubidium, strontium, and particularly boron, which are three to seven times higher than the Clarke values of these elements in the earth's crust. According to spectral analysis data the andesites, dacites and their tuffs from the region of the Dogdinsk trough and the Saltaga-Tas Mountains were found to contain high concentrations of lead, arsenic, mercury, titanium, vanadium, nickel, cobalt, and copper.

The volcanic activity in the fourth stage (Lower Cretaceous ?), which coincides with the fold formation in the Verkhoyansk-Kolyma geosyncline, developed everywhere under subaerial conditions. The Lower Cretaceous age of the volcanic formations was authentically established only in the Momo-Zyryansk basin. Very characteristic is the fact that the centers of volcanic activity moved in the Lower Cretaceous from the Alazeysk uplift of the Kolyma central massif to the zone of marginal anticlinoria and the intermontane basins (Momo-Zyryansk, Syuryukhyatsk, etc.). Perhaps this is connected with the formation in the fringe areas of the Kolyma central massif of vertical displacements involving large blocks of the Paleozoic basement as a result of the activity of the fold-forming movements in the Mesozoic geosynclinal zone.

The distribution of the volcanic activity products in the Lower Cretaceous time was associated with the linear zones of deep-seated

faults within which volcanic systems of the central type existed, as established by I. P. Shlykov in 1955 in the Andrey-Tas Range, and by V. A. Krasnovskiy in 1958 in the Saltaga-Tas Range. Predominantly developed among the volcanic formations are andesites interbedded with litho-crystallo-clastic and agglomeratic tuffs (Andrey-Tas Range). Well preserved within the limits of the volcanic formations are necks consisting of dioritic porphyrites, to a lesser extent of basalts and andesites, and volcanic pipes filled with agglomeratic tuffs (the basin of the Nikanda and Syryuktyakha streams, according to data of A. A. Zamarayev, I. P. Shlykov and Yu. A. Yunusov).

In 1955, I. P. Shlykov was the first to point out that the small gold content present in the Andrey-Tas Range is due to the presence of quartz veins associated with the Lower Cretaceous volcanic formations which have undergone hydrothermal alterations near the centers of the andesitic lava flows. Associated with the dioritic porphyrites which comprise the stocks and necks in the Syuryuktyaka intermontane basin are the analogous ilmenite and magnetite ore showings which constitute the source of the Syryuktyakha alluvial placers.

The fifth stage (Upper Cretaceous — Paleogene ?) of volcanic activity appeared only in a small (30 km^2) section of the Alazeysk uplift and was reflected in the efflux of acid lavas. In the liparitic tuffs, alternating with the effusives, I. N. Karbivnich was able to detect an assemblage of flora on the basis of which the volcanic rocks were dated as Upper Cretaceous — Paleogene. The volcanic strata consist of liparites, trachytes, and their tuffs, which form two fields around the subvolcanic intrusives consisting of syenite-porphyries and granite-porphyries and confined to the closed end of the anticline. The geochemical characteristics of the liparites, trachytes, and their tuffs, as well as of the syenite-porphyries and granite-porphyries, consist in the high (ten or more times the Clarke value) concentration of boron and the presence of tin, chlorine, zirconium, cerium, and yttrium in quantities up to five times greater than the Clarke values. According to I. N. Karbinovich's data (1954) the deposits of tin and other elements in the Alazeysk plateau are related to the acid and alkaline effusives and subvolcanic intrusions of Upper Cretaceous — Tertiary age. Accessory minerals, such as cassiterite, monazite, zircon, and tourmaline, are to be found both in thin aplite and quartz veinlets cutting across the liparites and trachytes, and in the granite-porphyries and syenite-porphyries of the subvolcanic intrusions.

2. VOLCANISM IN THE TERRITORY OF THE VERKHOYANSK-KOLYMA MESOZOIC FOLDED ZONE

The beginning of volcanic activity (first stage) in the northwestern and northern parts of the Verkhoyansk-Kolyma folded zone coincides with the period of most intensive folding. Maximum volcanic activity (second stage) was attained in the Lower Cretaceous period when the, so-called, batholith-like granitoid masses were formed in the youthful folded zone [5]. Finally, the volcanic formations of the concluding (third) stage (Upper Cretaceous — Paleogene) are developed only in the most mobile parts of the Verkhoyansk-Kolyma folded zone (in the Kondakovskoye plateau, in the Dzakhtardakh Mountains of the Polousnyy Range and in the Ulakhan-Sis Range).

The first stage of volcanism. The products of the first stage of volcanic activity in the northwestern part of the Verkhoyansk-Kolyma folded zone are andesites dacites, and liparites, which alternate with faunally characterized sandstones and schists of the Upper Jurassic. Pyroclastic formations are exceedingly poorly developed in the Upper Jurassic schistose sandstone strata. The roots of the Upper Jurassic effusives represented by sills and dikes consist of gabbroic diabases, quartz porphyries, and occasionally by granite-porphyries. Like the effusives, they are also crumpled into common folds with the Upper Jurassic strata of schistose sandstones. The Upper Jurassic effusive formations outcrop only in the western part of the Polousnyy Range. The total development area of the Upper Jurassic effusive-sedimentary formations in northeastern Yakutiya comprises about 400 to 500 square kilometers.

According to the data of chemical and spectral analyses, the Upper Jurassic effusives contain a high proportion of arsenic, cobalt, copper and mercury, and their acid varieties ar[e] enriched by barium, tin, beryllium, and molybdenum.

The second-stage volcanism (Upper Jurassic — Lower Cretaceous) is characterized by intensive acid lava flows.

We established the age of the second-stage volcanic formations tentatively as Upper Jurassic — Lower Cretaceous on the basis of following data.

1. The effusive represented by liparites and liparite-dacites, containing a very subordinate amount of their tuffs, are everywhere emplaced in intensively dislocated and faunally characterized Upper Jurassic schistose sandstone deposits. The effusives themselves folded in the more recent stage of Cimmerian tectogenesis.

2. Time-wise the effusives are synchronous

with the granitoids of the complex of batholith-like intrusions in Northeastern U. S. S. R. Therefore, many investigators point both to the existence of a metamorphism of volcanic formations caused by the granitoids and to liparitic flows overlying the granitoid intrusions (for example, in the region of the Elikchansk massif in the Polousnyy Range, according to I. P. Shlykov's data).

In the Polousnyy Range, Ye. M. Shesterenkin found a pebble of the granites from the batholith-type massifs in a horizon of the basalts conglomerates underlying the rhyolites.

3. The absolute age of the granites in the batholith-like intrusives and of the rhyolites is identical (within the limits of 125-150 million years according to determinations made in the Laboratories of the Yakutian Branch of the U. S. S. R. Academy of Sciences, the VNII-1, and the VSEGEI).

Rhyolites, dacites, and rarely their tuffs, form considerable fields (covering an area of up to 100 km^2) in the central and eastern parts of Polousnyy Range, and are 15 to 20 kilometers apart. The thickness of the effusive Lower Cretaceous strata ranges in the various fields from 250 to 500 m. The distribution of effusive fields is determined by the ruptured zone confined to the axial part of the Polousnyy Range, or to the lateral branches of the main Kolyma fault separating the Mesozoic folded zone from the Polousnyy marginal geanticline of the central massif. Numerous dikes and stocks of granite-porphyries, quartz porphyries, and granodiorite-porphyries are located within the limits of the effusive fields and the spaces between them. These subvolcanic intrusions probably are the remains of the main flow centers localized within the limits of the linear zones.

A few of the stocks coincide with the typical systems of the central type (Kuobakh, Tirekhtyakh, and others). The most deeply eroded parts in them are composed of granite-porphyries, while the outer edges, 50 to 70 m thick, consist of quartz porphyries. Flows of acid lava could have been extruded from chambers located not far from the surface of the ground. The possible existence of such shallow depth volcanic foci is postulated by Ye. K. Markhinin on the basis of a study of modern volcanoes in the Kurile Islands [4].

The subvolcanic quartz-porphyry and granite-porphyry intrusives were subjected to intensive hydrothermal alteration as manifested by regional greisenation of these formations and the enclosing sedimentary and effusive rocks. The volcanic foci which previously discharged acid lavas served as the source of hydrothermal solutions under the influence of which granite-porphyries and quartz-porphyries were intensively greisenized. This fact is evidenced by the presence of topaz, fluorite, lepidolite, and sometimes of such accessory minerals as beryl and monazite, in the granite-porphyries and quartz-porphyries forming the stocks, and in the rhyolites of the enclosing formation. The rhyolites, granite-porphyries, and quartz-porphyries are enriched with beryllium, boron, lithium, fluorine, arsenic, molybdenum, and lead, the percentages of which, judging by the data of chemical and spectral analyses, usually exceed the respective Clarke values in the earth's crust.

In certain stocks quartz-porphyries and granite-porphyries are so highly greisenized that they form deposits of the stockwork type. Apart from greisen and stockwork zones there are peculiar orebodies of the extrusion breccia type in the Odinokoye and Chokhchurskoye deposits. These are confined to the contacts of steeply dipping stocks and dikes of quartz-porphyries and granite-porphyries. This type of deposit is genetically associated with subvolcanic intrusions and is described in the Lesser Khingan, and was described in the works of A. M. Kalik and G. V. Itsikson [2, 3].

The third stage of volcanism embraces the end of the Upper Jurassic and the beginning of the Paleogene. In 1957, volcanic formations of this type were identified by G. I. Mikheyev in the Kondakovskoye upland (the lower reaches of Indigirka River), in 1958, by the author of this paper and Ye. M. Shesterenkin in the southern part of Polousnyy Range, and in 1959, by the author, K. V. Yablokov and Ye. M. Shesterenkin in the Ulakhan-Sis Range. However, a flora assemblage permitting the lower part of the effusive strata to be reliably assigned to the Upper Cretaceous was found only in the tuffs in the Kondakovskoye upland. The Paleogene age of the upper section of the volcanic formation was identified by us only tentatively.

The volcanic activity in the third stage developed under the conditions of already well-consolidated Mesozoic folding. It was restricted to the latitudinally- and meridionally-striking faults containing a great number of central vents. The faults are confined to the weak, ruptured zone of the main Kolyma fault and to the rather recent sections of the folded zone (the region of Kondakovskoye plateau).

We observed that most of volcanic vents of the central type coincide with the intersections of the latitudinal and meridional faults (Polevaya Mountain, Khara-Sis, and Kotel).

Andesitic and andesitic-basaltic lavas prodominate everywhere, the role of the dacites and basalts being strictly subordinate. Pyroclastic formations are developed only near the centers of volcanic activity and are represented by tuffs and welded tuff of andesitic origin. The

thickness of the individual andesite and andesite-basalt mantles fluctuates over a wide range from 2 to 30 m, and the total thickness of the volcanic formations varies from 200 to 900 m. Subjacent to the effusive strata are beds of pyroclastic rocks which, in the vicinity of individual volcanoes (Dzhakhtardakh Mountain), attain 350 m in thickness according to Ye. M. Shesterenkin's data. The area covered by the fields of volcanic formations varies between 25 and 300 square kilometers.

Fields of effusive formations and their tuffs are usually situated around the systems of the central type which are filled either by well crystallized igneous rocks (diorites, dioritic porphyrites, monzonites, and syenites), or by andesites and basalts, which form peculiar plugs in their vents. By way of an example of a volcano of the first type we shall characterize the volcanic system of Polevaya Mountain in the Ulakhan-Sis Range and of Khara-Sis Mountain in the Polousnyy Range. As an example of the volcanoes of the second type, it might be well to describe the central-type system of Kotel Mountain in the Kondakovskoye plateau.

The volcano of Polevaya Mountain is situated on the southern spurs of the Ulakhan-Sis Range. Together with the field of effusive formations it occupies an area of 30 square kilometers. The central part of this field is a caldera-like funnel of ellipsoidal shape about 7 km^2 in area. This cirque-like funnel, filled by subvolcanic monzonitic intrusion, is surrounded by a wide field of volcanic formations represented by andesites and andesite-basalts at the top, andesitic welded tuffs in the middle part, and a thick (up to 100 m thick) stratum of alternating tuffs and welded tuffs of dacitic and andesitic composition at the bottom of the section. Similar, usually more eroded, volcanic systems are characteristic of the eastern part of Ulakhan-Sis Range; they are less well-developed in the southern part of the Polousnyy Range.

The Khara-Sis neck is a central-type volcanic system of a more complex structure. It consists of diorites and monozites intruded by granites and granite-porphyries (Figure 2).

Under the action of the granitic melt upon the diorites and monozites, syenites and syenite-porphyries were formed. The volcanic systems of the Khara-Sis Mountain has undergone a considerable degree of erosion. Consequently, only small (up to 0.1 km^2) sections of andesites, dacites, and their welded tuffs have been preserved around it. Dikes of andesitic and dacitic composition, which represent the roots of the effusive formations, extend outward from the central system in latitudinal and meridional directions. Similar, two-phase subvolcanic intrusions filling the vents of Upper Cretaceous volcanos are well developed in the southern and southwestern parts of the Polousnyy Range. In the Dzhakhtardakh Mountains they were investigated by Ye. M. Shesterenkin, in the Selennyakh ridge — by the author, V. V. Razborshchikov, and R. R. Zivert.

Finally, the Upper Cretaceous — Paleogene volcanoes, in which the chimney is sealed by a basaltic or andesitic plug, are characteristic of the Kondakovskoye plateau. The best known here is the Kotel Mountain volcano, which in the present section is a regular, truncated cone about 80 m high, with a base diameter of about 600 m and 30 to 35° slopes. Around it are numerous sheets and flows of andesites and andesite-basalts aggregating 450 m in thickness, and covering an area of about 700 square kilometers. Very interesting is the fact that the andesite and andesite-basalt flows, extending for 30 km out from the volcanic system — 10 to 15 high and 20 to 80 m wide, according to G. I. Mikheyev — are confined only to the valleys of the recent rivers. These flows are very similar to those described by Ye. K. Ustiyev for a young volcano in the basin of the Bol'shoy Anyuy River [10]. In this connection it is quite possible that some volcanoes in the Kondakovskoye upland are younger than we have supposed.

In immediate proximity of the volcano vent, at its foot, one may observe the beds of a volcanic formation consisting of tuffs containing a great number of volcanic bombs. These tuffs and andesitic and basaltic lavas encircling the volcano vent are intensively altered and transformed into a characteristic reddish formation resembling the effusive red beds described by B. I. Piyp for the basin of the Avacha, Rossosh, Gavanka, and Kalacheva Rivers in Kamchatka [7]. The high content of ferrous iron, which — according to the data of many investigators — forms as a result of oxidation of ferric iron compounds under the effect of hydrothermal solutions or fumarolic sublimates [1, 8, 11, 12], is very characteristic of the effusive red beds of the Kotel Mountain volcano.

The general evolution pattern characteristic of recent volcanoes in the Kondakovskoye plateau (Kotel, Pobochnyy, etc.) appears to us as follows:

1. Effusion of andesitic lava along the fissures in the northwestern ruptured zone.

2. Sealing of the individual fissures by crystallizing lava with the formation of a series of andesite and andesite-basalt dikes, and the origination of a volcanic system of the central type.

3. Breaking through of a volcanic pipe by andesite-basaltic lava accompanied by repeated ejections of ash and volcanic bombs.

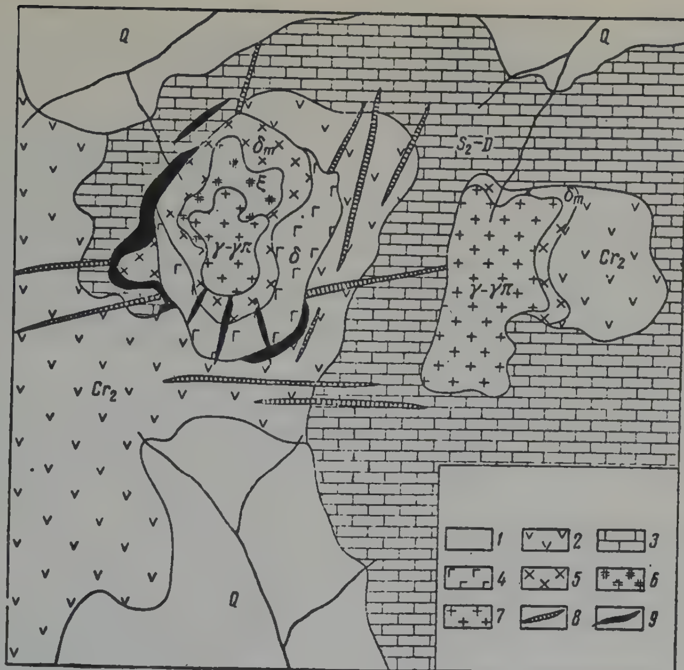


FIGURE 2. Sketch of the geologic structure of the Mount Khara-Sis region

1 - Quaternary deposits (pebble beds, silts); 2 - andesites, dacites, and their tuffs; 3 - limestones with thin layers of argillaceous shales; 4 - quartz-diorites; 5 - monzonites; 6 - syenites and syenite-porphyries; 7 - granites and granite-porphyries; 8 - andesite and dacite dikes; 9 - magnetite-pyroxene, farnet-pyroxene, amphibole, and vesuvianite skarns.

4. Plugging of the volcano pipe by crystallizing andesites or andesite-basalts.

In the last three years manifestations of mercury were found to be associated with the subvolcanic intrusions of Upper Cretaceous age in the Polousnyy Range (in the region of Kalychan and Nal'chik, according to M. A. Galkin's data), and the metalliferous potentialities in the Ulakhan-Sis Range were established with respect to gold. Gold-bearing zones of sulfidized andesites were located by us in the vicinity of Mount Polevaya, and I. N. Karbivnich discovered emulsion gold in the Zeysk deposits associated with the subvolcanic intrusion of monozites in the Kandidatskaya Mountains.

The metal content of the volcanic formations in the Kondakovskoye upland is still amost unstudied. According to G. I. Mikheyev, the effusives and volcanic tuffs around Kotel Mountain are enriched by pyrites and magnetite, which together account for up to 5% of the rock volume.

CONCLUSIONS

Mineralogical and petrographic investigations carried out by us in recent years (1951-1959) in northeastern Yakutiya made it possible for us to outline the described pattern of volcanic activity, and for the first time to establish certain data on the metal content of the volcanic formations and complexes of subvolcanic intrusions.

Characteristic of the central part of the Kolyma central massif (Alazeysk uplift) is the intense volcanic activity developing throughout the entire Mesozoic period. Among the volcanic formations, mainly of acid composition, the volcanic tuffs clearly predominate, with the effusives and subvolcanic intrusions playing only a subordinated role. Very little is known of the metal content of the volcanic formations of the Alazeysk uplift. All of the known titanium, iron, tin, and gold ore manifestations are associated with subvolcanic minor intrusions which accompanied the volcanic activity throughout all five stages.

In the marginal geanticlines of the Kolyma central massif intense volcanic activity began to develop in Upper Jurassic time when a series of deep-seated faults developed, including the main Kolyma fault at the junction of the Paleozoic carbonaceous and Mesozoic

schistose-sandstone series. Along with the extrusion of lavas along the fissures, volcanoes of the central type developed in certain deep faults (Saltaga-Tas Mountains in the Selennyakh Ridge, the Dogdinsk trough in the Tas-Khayakhtakh Range). Very characteristic of the volcanism in the marginal geanticlinal zones in the Kolyma central massif are the predominance of average-composition lavas over basic and acid lavas; an exceedingly weak development of volcanic tuffs; a more intense manifestation of subvolcanic intrusions than in the Alazeysk uplift; and finally, diversified mineralization, including deposits of commercial importance. Mercury and titanium were discovered in association with the effusives in the Tas-Khayakhtakh and Andrey-Tas Ranges. Some subvolcanic intrusions appear to be metalliferous with respect to gold, titanium, iron, and rare metals.

In the Verkhoyansk-Kolyma Mesozoic folded zone all volcanic formations are localized in the northern section which embraces the Polousnyy and Ulakhan-Sis Ranges and the Kondakovskoye uplift, and in the zone of the main Kolyma fault (the western part of Selennykh Ridge). The laval flow was extruded under subaerial conditions along the fissure zones or from central vents (volcanoes of the Kondakovskoye plateau, the Dzhakhtardakh Mountains in the Polousnyy and Ulakhan-Sis Ranges).

Unlike the Kolyma central massif, rhyolites and dacites are clearly predominant among the volcanic formations of Upper Cretaceous age here. Andesites are of very secondary significance. The Upper Cretaceous volcanic activity is characterized by lava extrusion of primarily andesitic composition from linear fissures and the systems of the central type. Pyroclastic formations have a very limited development only near the volcanoes. Volcanic activity in all of the stages was accompanied by injection of numerous subvolcanic intrusions, of which the Lower Cretaceous formations are potentially metalliferous with respect to rare metals, particularly to tin, and, with regard to gold and rare metals — the Upper Cretaceous — Paleogene magmatic complexes.

REFERENCES

1. Belyankin, D. S., K kharakteristike brekchiyevykh i poloschatykh lav vulkana El'brus. [THE CHARACTERISTIC OF BRECCIA AND STREAKED LAVAS OF THE ELBRUS VOLCANO]: Doklady, Akad. Nauk SSSR, t. 21, no. 5, 1936.

2. Itsikson, G. V., Gidrotermal'nyye izmeneniya vmeshchayushchikh porod olovorudnogo mestorozhdeniya na Malom Khingane. [THE HYDROTHERMAL ALTERATIONS OF THE COUNTRY ROCKS OF THE LEAD ORE DEPOSITS IN THE LESSER KHINGAN]: Gosgeoltekhizdat, 1956.

3. Kalik, A. M., O geneticheskoy svyazi olovyannogo orudeneniya a vulkanicheskimi porodami na primere mestorozhdeniy Malogo Khingana. [THE GENETIC CONNECTION BETWEEN STANIFEROUS MINERALIZATION AND THE VOLCANIC ROCKS AS EXEMPLIFIED IN THE LESSER KHINGAN DEPOSITS]: In the book, "Materialy k II Vses. petrograf. soveshch". Tashkent, 1958.

4. Markhinin, Ye. K., K istorii razvitiya vulkanizma na Kuril'skikh ostrovakh. [ON THE HISTORY OF VOLCANIC ACTIVITY ON THE KURILE ISLANDS]: In the book, "Materialy k II Vses. petrograf. soveshch". Tashkent, 1958.

5. Matveyenko, V. T., and Ye. T. Shatalov, Razryvnyye narusheniya, magmatizm i orudeneniye Severo-Vostoka SSSR. [FAULTING, MAGMATISM, AND MINERALIZATION IN NORTHEASTERN USSR]: In the collection, "Zakonomernosti razmeshcheniye poleznykh iskopayemykh v zemnoy kore", t. 1, Izd-vo Akad. Nauk SSSR, 1958.

6. Naboko, S. I., Izverzheniye Bilyukaya — pobochnogo kratera Klyuchevskogo vulkana v 1938 g. [THE ERUPTION OF BILYUKAY — THE SUBORDINATE CRATER OF THE KLYUCHEVSKIY VOLCANO IN 1938]: Tr. Labor. vulkanolog., Akad. Nauk SSSR i Kamchatskoy vulkanol. stantsii, vyp. 5, 1947.

7. Piyp, B. I., Materialy po geologii i petrografii rayona rek Avachi, Rassoshi, Gavanki i Kalachevy na Kamchatke. [MATERIALS ON THE GEOLOGY AND PETROGRAPHY OF THE AVACHA, RASSOSH, GAVANKA, AND KALACHEVA RIVER REGIONS]: Tr. Kamch. kompleksn. ekspeditsii 1936-1937 gg., vyp. 2, Izd-vo Akad. Nauk SSSR, 1940.

8. Pushcharovskiy, Yu. M., Skhema tektonicheskogo rayonirovaniya Severo-Vostoka SSSR. [A SCHEME FOR THE TECTONIC ZONING OF NORTHEASTERN USSR]: Doklady, Akad. Nauk SSSR, t. 105, no. 5, 1956.

9. Saks, V. N., Geologiya i petrografiya Alazeyskogo plato. [THE GEOLOGY AND PETROGRAPHY OF THE ALAZEYSK PLATEAU]: Tr. Gorno-geol. upr., vyp. 5, 1941.

10. Ustiyev, Ye. K., Molodoy vulkan v basseyne r. Bol'shogo Anyuya. [A RECENT

VOLCANO IN THE BASIN OF THE BOL'SHOY ANYUY RIVER]: Kolyman no. 12, 1953.

Ustiyev, Ye. K., Nekotoryye osobennosti mekhanizma proiskhozhdeniya poristosti lav na primere poznechetvertichnogo trakhibazal'tovogo potoka doliny Monni. [CERTAIN CHARACTERISTICS OF THE GENETIC MECHANISM OF LAVA POROSITY AS EXEMPLIFIED BY THE LATE QUATERNARY TRACHYBASALTIC FLOW IN THE MONNI VALLEY]: Izv. Akad. Nauk SSSR, ser. geol., no. 12, 1956.

12. Favorskaya, M. A., O nekotorykh vtorichnykh izmeneniyakh kislykh effuzivov Yuzhnogo Primor'ya. [CERTAIN SECONDARY ALTERATIONS OF THE ACID EFFUSIVES IN SOUTHERN PRIMOR'YE]: Izv. Akad. Nauk SSSR, ser. geol., no. 7, 1956.

The Geological Institute of the
Yakutian Branch of the
U. S. S. R. Academy of Sciences,
Yakutsk

Received, 16 February 1960

THE PREDOMINANT STRUCTURES OF NORTHEASTERN CHINA AND OF THE ADJACENT TERRITORY OF THE SOVIET FAR EAST[1]

by

Yu. A. Khodak and Sung Shu

The paper describes the principal geologic problems of northeastern China and the adjacent territory. The main geotectonic features and structures formed by the corresponding structural stages are identified, and a series of deep-seated regional faults striking in four directions is delineated.

* * * * *

In the course of work by the Amur (Council of the U. S. S. R. Academy of Sciences for the Study of Productive Resources) and Heiluntsiang (the Academy of Sciences of the Chinese People's Republic) complex expeditions, the authors have investigated an extensive area of northern China extending from the Greater and Lesser Khingan Ranges and the Khanka region to the Liaotung Peninsula and Korea, an area of about 1 million square kilometers, and also the adjacent areas of the Soviet central Amur retion.

THE MAIN GEOTECTONIC FEATURES

The investigated areas are situated at the junction of the largest geotectonic features: the Chinese-Korean Pre-Sinian shield, the Mongolian-Okhotsk folded belt, and the Sikhote-Alin" Mesozoic folded zone. The area is characterized by complex block structure, with repeated and non-synchronous manifestations of folding and magmatism in different zones, as well as by the presence of central massifs detached from the shield during the Hercynian folding and representing the remnants of the northwestern offshoot of the ancient Chinese platform (Figures 1-3). Developed in these regions are various complexes of sedimentary and igneous rocks ranging from the Lower Proterozoic through the Cenozoic.

The oldest geotectonic feature in the region — the Chinese-Korean shield — is situated within the boundaries of Liaonin Province, the southeastern part of Girin province, and Korea. It is characterized by an extensive development of Pre-Sinian metamorphic formations and granitoids. Two structural stages of the folded basement can be identified in the shield, and ascribed tentatively to the Lower and Upper Proterozoic. They were disrupted by Pre-Sinian (mostly Pre-Upper Proterozoic) granitoids [16, 18]. The structural stages of the platform mantle correspond to the Sinian-Ordovician, Middle Carboniferous — Permian, Mesozoic (Jurassic-Cretaceous), volcanic in places, and the Cenozoic, sometimes represent by basalts. In some places the shield exhibits zones of Hercynian granitoids which disrupt the deposits. On certain occasions minor intrusion of, possibly, Yanshan granitoids also may be identified.

North of the shield is the southern offshoot o the Mongolian-Okhotsk folded belt, which hence forth will be called the Dunbey-Priamurian Hercynian folded zone. This offshoot is characterized by generally northeasterly striking Hercynian structures and by platform-type Mes zoic structures (unstable-platform structures) i contradistinction to the sublatitudinal strike of the Middle Paleozoic and older structures of the northern offshoots in the mountain belts and ranges of Tukuringra and Dzhagdy, belonging to the Mongolian-Okhotsk folded zone proper (according to L. I. Krasnyy's concepts [6]), where the Mesozoic folded structures are composed o both continental and marine formations.

The Dunbey-Priamurian Hercynian folded zone covers the area from the central Greater Khingan to the Badzhal'skiy Range and the Ussu River, from the northern slope of the shield (along a line between Chifyn' to Yangs'tce) to th southern slopes of the Tukuringra and Dzagdy Ranges. The area is characterized by an unusually extensive development of Paleozoic

[1]Glavneyshie struktury severo-vostoka Kitaya i sopredel'noy territorii Sovetskogo dal'nego vostoka, (pp. 97-110).

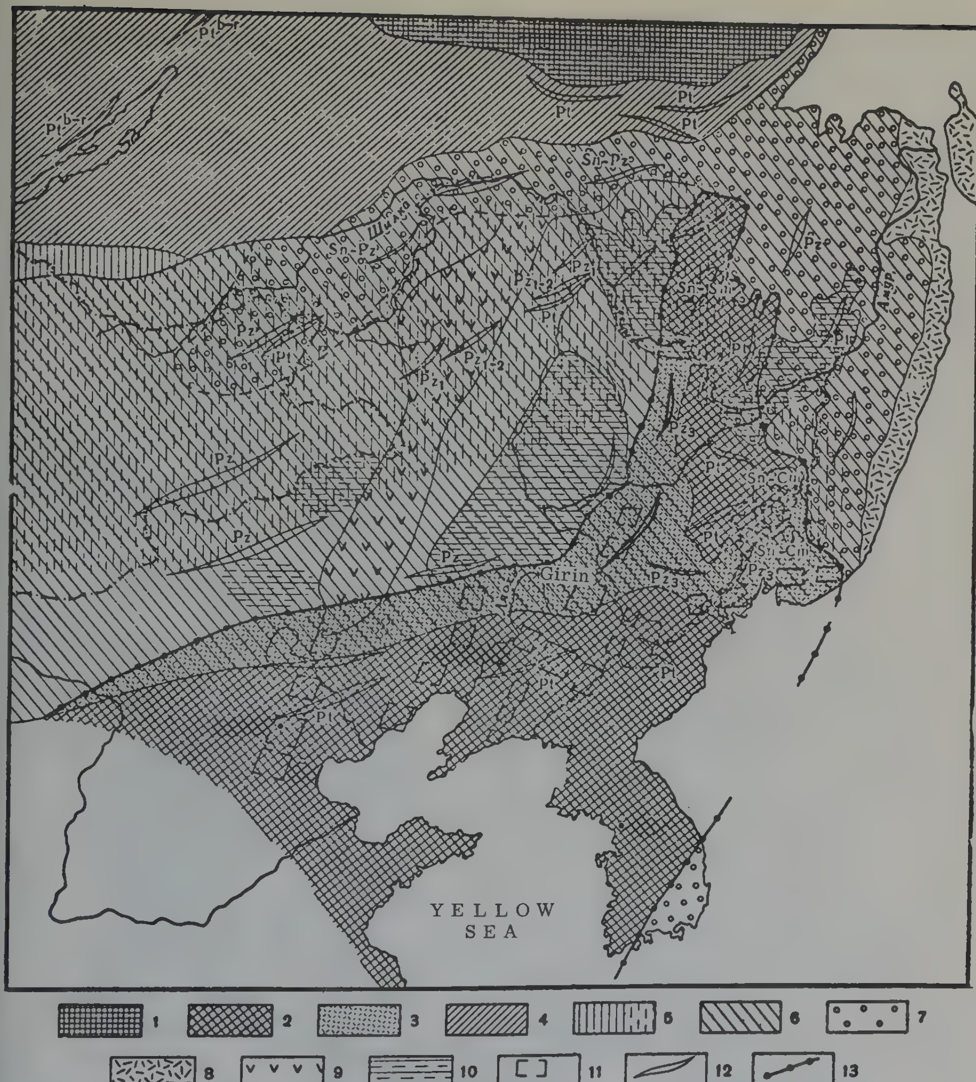
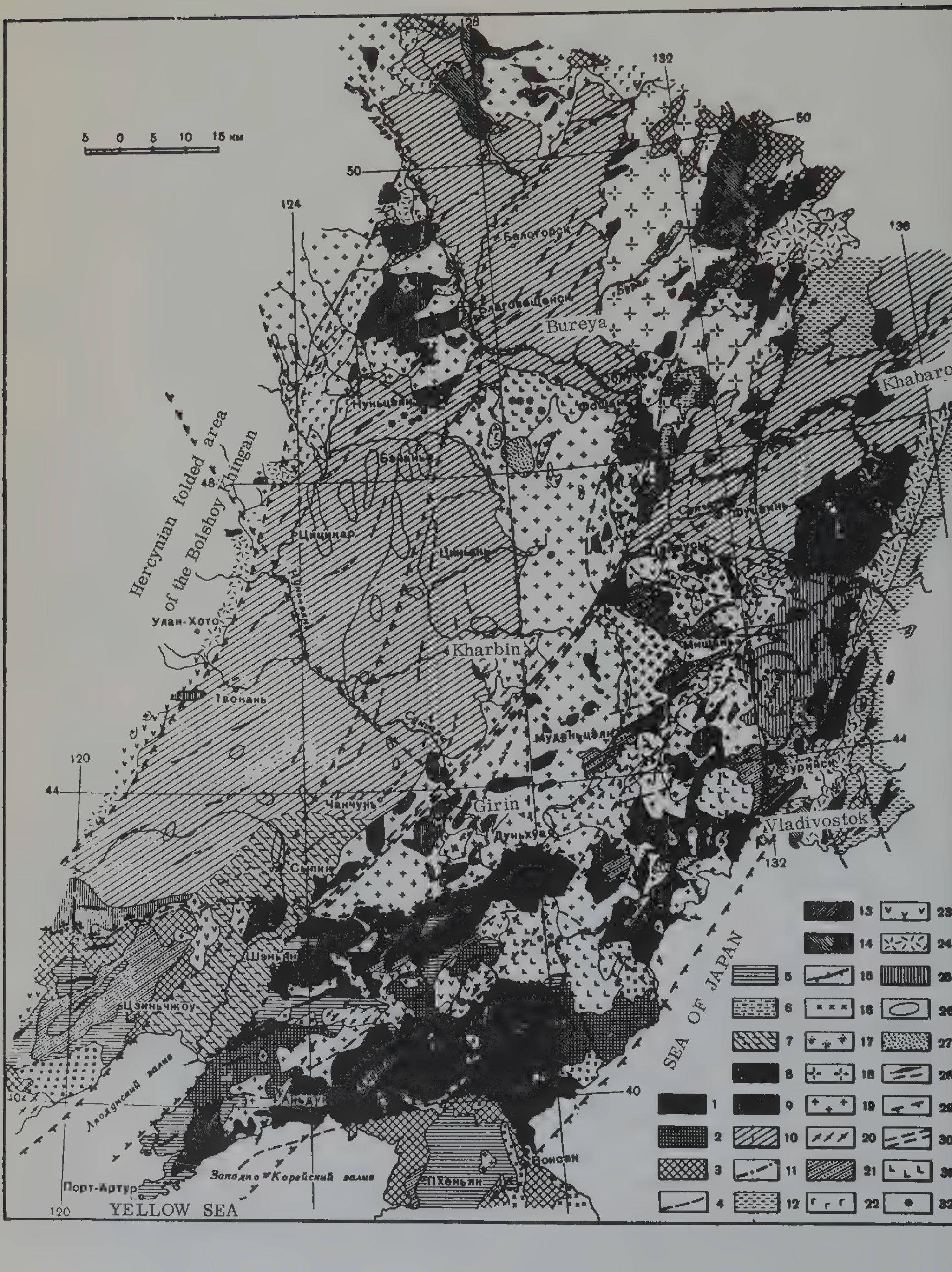


FIGURE 1. Map of the geologic position of Northeastern China within the overall structural configuration of Eastern Asia.

Compiled by Yu.A. Khodak (1958-1960). 1 - Archean folding; 2 - Proterozoic (Pre-Sinian) folding; 3 - Bureinsk-Girin offshoot of the Chinese-Korean shield; 4 - Baykalian and Riphean foldings; 5 - Baykalian-Caledonian (in the eastern part) and Caledonian (in the western part) foldings; 6 - Hercynian folding; 7 - Mesozoic (Iyen'shanian) folding; 8 - Cenozoic folding; 9 - Mesozoic effusives of the Greater Khingan; 10 - Mesozoic major troughs; 11 - the main zones of Iyen'shanian diastrophism in the ancient basement; 12 - trends of folds: Pre-Sinian (Pt), Sinian-Lower Paleozoic (Sn-Pz; Sn-Cm), Hercynian (Pz); 13 - the northern boundary of the ancient Chinese platform.

nitoid massifs (especially Hercynian) which imilated a considerable part of the Pre-sozoic rocks and which form a huge, multi-se batholith. In the Hercynian folded zone s possible to distinguish two structural stages he Pre-Sinian basement, which we compared the complex [16, 18] overlying the Archean he Aldanian shield. These stages are dis-ted by Pre-Sinian (primarily Upper Proterozoic) granitoids. One also may observe here the Sinian-Cambrian folded mantle intruded by Caledonian granitoids. Identifiable upward in the section are the structural stages of the Hercynian folded basement, which correspond to the Silurian (?)-Devonian, Carboniferous-Permian and are disrupted by Early (Pre-Carboniferous -- Permian) and Late Hercynian granitoids. The structural stages of the platform


5 0 5 10 15 км
Hercynian folded area of the Bolshoy Khingan
Bureya
Khabarovsk
Kharbin
Girin
Vladivostok
SEA OF JAPAN
YELLOW SEA
Белогорск
Благовещенск
Цицикар
Улан-Хото
Таонань
Чанчунь
Сыпин
Шэньян
Цзиньчжоу
Ляодунский залив
Порт-Артур
Западно-Корейский залив
Пхеньян
Вонсан
Муданьцзян
Уссурийск

mantle correspond to Mesozoic (Jurassic-Cretaceous) formations, which are frequently of volcanic origin, and which sometimes contain minor intrusions of Iyenshanian granitoids, and to Cenozoic formations represented by basalts.

The Dunbey-Priamurian Hercynian folded zone displays a number of major tectonic features representing a system of upthrust and down-faulted blocks of the Pre-Sinian and Paleozoic folded basement:

1. The Hercynian zone of the Greater Khingan (and western Lesser Khingan) is characterized by the widespread development of Middle Paleozoic geosynclinal deposits and the Early Hercynian granitoids cutting across them. Vast (areally) fields of Mesozoic effusives fringe the eastern Greater Khingan from west to east and separate it from the structures of the Argun' uplift and the Soviet Transbaykal regions already related to the northern offshoot of the Mongolian-Okhotsk folded belt.

2. The Zeysk-Sunliao subsidence area is filled with platform-type continental-lacustrine Meso-Cenozoic deposits overlying the Hercynian folded structures. This area is divided by the central zone of Lesser Khingan composed of Hercynian granitoids and Cenozoic basalts, into the Zesk-Bureinsk and Sunliao basins.

3. The Bureinsk-Girin uplift, together with the Ussuri-Khanka block detached from the former, represent the northeastern offshoot of the ancient Chinese platform which was reworked by Hercynian folding. Pre-Sinian central massifs, separated by zones of Upper, and occasionally Middle Paleozoic folded structures, are identifiable within the limits of the uplift. The largest massifs are the Khingan-Bureinsk, Vandaashansk, and Ussuri-Khanka massifs incorporated by E. Liangtsiun and Yu. A. Khodak [4, 17] in the disrupted Khegansk massif.[2]

Well developed in the Vandaashansk massif are Pre-Sinian granitoids which also may be noted locally in other massifs. Vast areas along the fringes of the uplift are occupied by Hercynian granitoids. Mesozoic coal measures and effusive formations are extensive. Sinian-Cambrian folded structures and the Caledonian granitoids cutting them, occur on the northern and northeastern fringes of the uplift. In the northern part of the uplift at the junction with the Mesozoic folded belt is the meridional Bureinsk foredeep filled with a thick formation of folded Mesozoic coal measures.

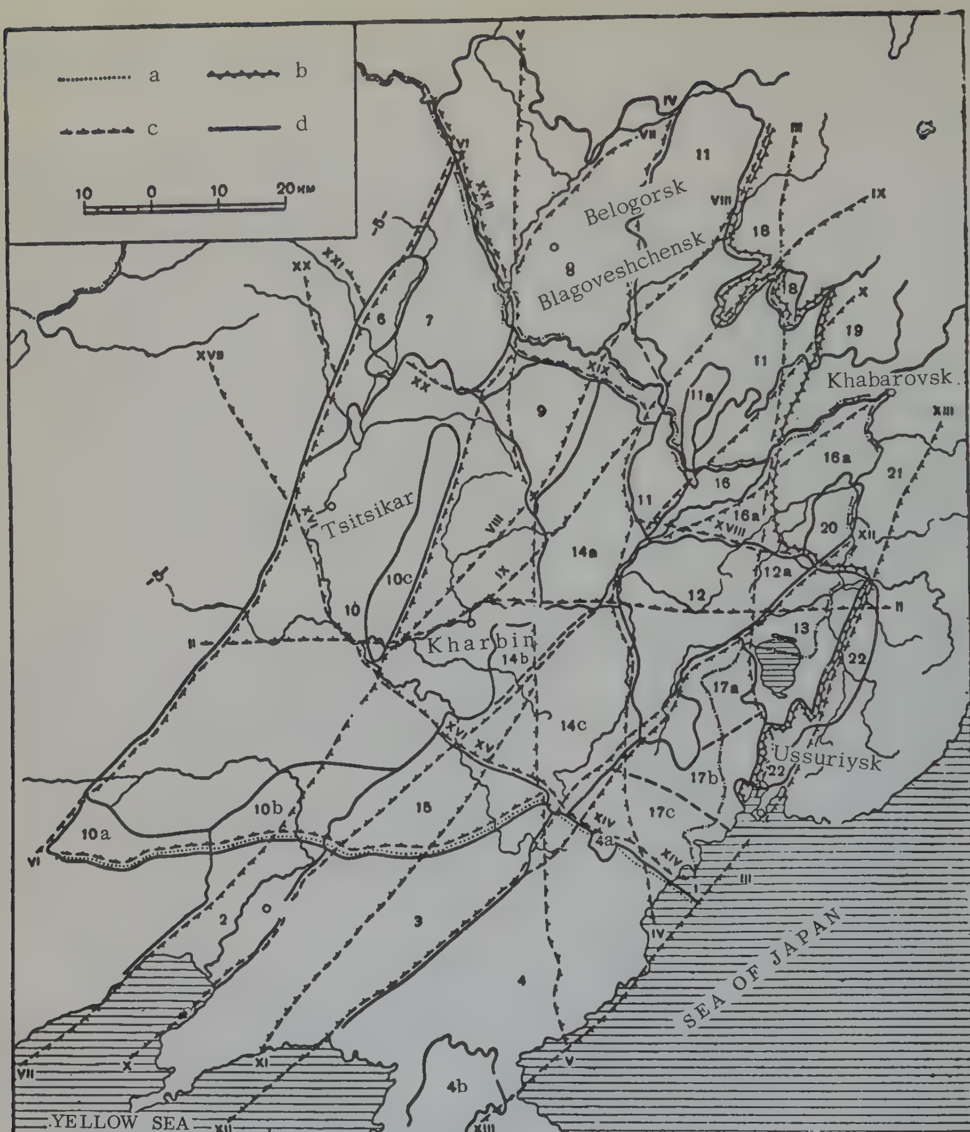
4. The Amur-Khanka subsidence area is filled with continental-lacustrine Mesozoic-Cenozoic deposits. This area encompasses the Amur-Sungari and Khanka basins, which separate the offshoots of the ancient blocks of the northern Nadan'khad-Alin', which are overlapped by Mesozoic geosynclinal structures, as well as of the Fynmishan'. The subsidence area is located at the junction with the Mesozoic folded belt.

5. The Ussuri-Khanka Pre-Sinian massif, investigated in Soviet territory by N. A. Belyaevskiy [2] and Yu. Ya. Gromov [3], is situated at the boundary with the Mesozoic belt. Well developed in the southwestern part of the massif are Sinian-Cambrian folded structures with intruding Caledonian granitoids, forming a wide geosynclinal zone in the vicinity of the

FIGURE 2. Tectonic map of Northeastern China and the adjacent territories

Compiled by Yu.A. Khodak and Sung Shu (1958-1959). A. Zone of Pre-Sinian folding. Structural stages of the folded basement: 1 - lower stage: Lower Proterozoic deposits; 2 - Upper stage: Upper Proterozoic deposits; 3 - undifferentiated Proterozoic deposits; 4 - boundaries of Proterozoic anticlinoria and synclinoria; 5 - Sinian-Paleozoic platform mantle of the folded basement; 6 - troughs in the Pre-Sinian basement filled with Sinian-Cambrian deposits; 7 - Subsidence zones of the Pre-Sinian basement and the Paleozoic platform mantle, overlain by thin Mesozoic formations. B. Zone of Hercynian folding. 8, 9 - deposits of the folded Middle and Upper Paleozoic (8 - geosynclinal deposits, 9 - parageosynclinal deposits); 10 - Middle and Upper Paleozoic folded structures covered by a formation of Mesozoic-Cenozoic deposits; 11 - boundary between the Pre-Sinian and Hercynian zones of folding. C. Zone of Mesozoic folding. 12 - the lower structural stage, Middle Carboniferous - Lower Triassic deposits; 13 - the middle structural stage, Triassic-Jurassic deposits; 14 - the upper structural stage, predominantly Jurassic - Lower Cretaceous deposits; 15 - boundary between the zones of Mesozoic and Hercynian foldings.
Other symbols: 16 - Pre-Sinian granitoids; 17 - Pre-Sinian and Caledonian (?) granitoids; 18 - Caledonian and Hercynian granitoids; 19 - Hercynian granitoids; 20 - Iyenshanian granitoids in the zone of Mesozoic folding and Early Cenozoic granitoids; 21 - superimposed Mesozoic basins, often containing acid and average effusives; 22-24 - zones of Cretaceous effusive development, basic (22), normal (23), acid (24), and their tuffs; 25 - Mesozoic-Cenozoic Khana depression; 26 - buried Mesozoic anticlinal structures of the Sungliao depression; brachyanticlines; 27 - Tertiary superimposed basins; 28 - fold trends; 29 - deep-seated faults of ancient origin reactivated in the Mesozoic-Cenozoic; 30 - grabens filled with Tertiary deposits; 31 - fields of Cenozoic basalts; 32 - volcanoes.

[2]According to L.I. Krasnyy's and A.M. Smirnov's nomenclature — Buriensk-Khegansk massif.



city of Spassk. The western part of the massif is strongly disrupted and is buried under the Mesozoic Khanka depression.

The Sikhote-Alin' geosyncline, which is a part of the East-Asiatic belt, was formed east of the described features on the extension of the Hercynian folds in the Triassic. In these regions one finds Triassic-Jurassic geosynclinal marine deposits. Two structural stages of Mesozoic formations can be identified in them. The lower stage forms a folded basement and is represented by Triassic-Middle Jurassic (?) deposits cut by granitoids, massifs, and ultrabasic and basic rocks. The upper stage consists of less-folded Upper-Jurassic (?) — Cretaceous coal-bearing deposits.

REGIONAL DEEP-SEATED FAULTS

A system of regional deep-seated faults of ancient origin, described by Yu. A. Khodak in 1958-1959, is developed in the territory of northeastern China and adjacent areas. This fault system broke up the Pre-Sinian basement into large blocks and was again active in the Paleozoic, Mesozoic, and Cenozoic. These faults are similar to the deep-seated faults described by A. V. Peyve [9-12], V. M. Sinitsyn [12-14], and A. Kh. Ivanov [5].

The shield is separated from the Hercynian folded zone by the grandiose Chanbay-Alashan' latitudinal deep-seated fracture zone clearly traceable from the city of Yan'tzsi to the

Alashan' and farther west. On the north the Dunbey-Priamurian Hercynian zone is delimited by the South Tukuringra-Dzhagdy sublatitudinal (SEE) deep-seated fracture zone [2a, 6].

Meridional deep-seated faults, which have disrupted its ancient basement and shield, are found in the eastern part of the Hercynian folded zone.

1. The Vladivostok-Bureinsk meridional fault is traceable along the eastern edge of the Bureinsk-Girin uplift from the outskirts of Vladivostok northward along the eastern fringe of the Suyfun basin, then farther east along the eastern fringe of the Vandaashansk[3] and Khingan-Bureinsk massifs, across the regions of the cities of Mishan', Baotsina, Birobidzhan, along the Bureinsk trough to the westward turn of the ancient folds in the southeastern part of the Dzhagdy Range.

2. The Bureinsk-Chengdinsk fault delimits the Pre-Sinian massifs on the north and can be traced northward from the city of Chengdin (Korea) along the Kayakhe River, following the Upper Paleozoic Kayakhe fault mapped by M. G. Organov, then farther along the Mudan'tszyan River to the Ilanya River, and along the western edge of the Khingan-Bureinsk massif to the Dzhagdy Range.

3. The Chanday-Blagoveshchensk fault passes through the body of the shield in Central Chanbayshan, follows the eastern fringe of the Sunliao basin toward the city of Blagoveshchensk, then passes north of it under the mantle of Mesozoic-Cenozoic deposits, where meridional basement structures were identified, and still farther on, along the eastern fringe of the Depsk syneclise to the junction of the Tukuringra and Dzhagdy Ranges.

A series of central Greater Khingan deep-seated faults is distinguishable in the western regions of the Hercynian folded zone. These faults proceed along the zone of Mesozoic effusives and divide the Greater Khingan into the Argun' and eastern Great Khingan uplifts and the basin between them.

Here one finds a series of northeasterly faults which have split the shield, the Hercynian and Mesozoic folded zones.

1. The western Greater Khingan fault separates the Mesozoic effusives trough in the central Greater Khingan from the Argun' uplift.

2. The west Sunliao fault extends along the western edge of the Depsk syneclise and passes farther southwest along the upper reaches of the Nun'tszyan River, then along the western edge of the Sunliao basin, and is traceable from the city of Chifyn' to Peking.

FIGURE 3. Map of tectonic zoning in Northeastern China and adjacent territories

a - zone boundary between Pre-Sinian and Hercynian foldings; b - zone boundary between Hercynian and Mesozoic foldings; c - boundary between the structural features; d - deep-seated faults of ancient origin reactivated in the Mesozoic-Cenozoic (the direction of block subsidence is indicated). Compiled by Yu.A. Khodak (1958-1960)
Principal tectonic features (figures as shown in the diagram). The Chinese-Korean Pre-Sinian shield: 1 - the Liaosin block; 2 - Liokhean Mesozoic trough; 3 - Liaokhe-Yalutzyan block; 4 - Chaybay-Korean block (4a - detached Khelun massif, 4b - Tedonganian basin). The Mongolian-Okhotsk folded belt (the southern - Hercynian offshoot - Dunbey-Priamurian folded zone). The Hercynian zone of the eastern Greater Khingan and western Lesser Khingan; 5 - geanticlinal zone of the eastern Greater Khingan; 6 - Dayanshuian Mesozoic trough; 7 - western Lesser Khingan geanticlinal zone. Zeysk-Sunliao subsidence area; 8 - Zeysk-Bureinsk Mesozoic basin; 9 - Central Lesser Khingan uplift; 10 - Sunliao Mesozoic-Cenozoic basin (10a - Kayluian Paleozoic trough, 10b - sunken Tunliao shield offshoot, 10c - Central Sunliao sunken arch). Bureinsk-Girin uplift (northeastern offshoot of the Chinese-Korean Shield): Pre-Sinian central massifs; 11 - Khingan-Bureinsk massif (11a - Sinian-Cambrian trough of the eastern Lesser Khingan); 12 - Vandaashanian massif (12a - Dakhechzhenian nose); 13 - the strongly disrupted Ussuri-Khanka massif (with superimposed Khanka Mesozoic basin). Middle Paleozoic structure-facies zones at the edges of the Bureinsk-Girin uplift; 14 - Laoelino-Tanvankhean geosynclinal zone (12a - Tsinkheyshan, 14b - Yuytsyuan, 14c - Chzhanguantsai subzones); 15 - The Girin geosynclinal zone; 16 - Budzhano-Fen'shuygan geosynclinal zone (16a - with superimposed Amur-Sungari basin); 17 - Tumyn'-Brodekovo geosynclinal zone (17a - Grodekovo, 17b - Taypinli, 17c - Yanbyan subzones). The East-Asiatic folded belt; 18 - Bureinsk trough; 19 - Badzhal'sk geenticlinal zone; 20 - Nadan'khada-Alin' anticlinorium; 21 - Bikinsk synclinal zone; 22 - Daubikhinsk geosynclinal zone.
Deep-seated faults: I - Chanday-Alashan; II - Khana-Taonan; III - Vladivostok-Bureinsk; IV - Bureinsk-Chengdinsk; V - Chanbay-Blagoveshchensk; VI - Western Sunliao; VII - Selemdzi-Liaokhe; VIII - Northern Bureinsk-Liaokhe; IX - Southern Bureinsk-Liaokhe; X - Sungari-Liaokhe; XI - Girin-Fen'shuili; XII - Khaykay-Yalutszyan; XIII - West Sikhote-Alin'; XIV - Yan'tspo-Dun'khua; XV - Girin; XVI - Sungari-Nuntszyan; XVII - Yalukhe; XVIII - North Fen'shuigan; XIX - Lesser Khingan; XX - Nun'tszyan-Beyan'; XXI - Kheykhe-Khyma.

[3]In these regions the fault coincides with the Sinkaysk structural fracture zone, according to M.G. Organov [19].

3. The Selemdzhi-Liaokhe fault follows the Nora, Selemdzhi, and Zeya Rivers and then to the southwest along the Sun'usk graben and the eastern edge of the central Sunliao subsidence arch toward the city of Tzin'chzhou and the mouth of the Kuankhe River.

4. The north and south Bureinsk-Liaokhe faults are, respectively, traceable along the Bureya, Khulan'khe, and Amgun' Rivers in the direction of the cities of Foshan' and Yuytsyuan'.

5. The Sungari-Liaokhe (lower Amur-Liaokhe) fault extends downstream along the Amur River (from the city of Nikolayevsk to the mouth of the Sungari River)[4] and then in a southwesterly direction along the Sungari River to the city of Tunkhe (separating the Khingan-Bureysk and Vandaashansk massifs), along the Sunliao graben through the regions of the cities of Girin and Shen'yan, and along the eastern shore of the Liaotung Bay. The Ilan'-Kukan fault is an offshoot of the Sungari-Liaokhe fault, and can be traced along the western fringe of the Middle Paleozoic trough and the Amur-Sungari basin which has developed over it, from the city of Ilan' to the city of Birobidzhan. L. I. Krasnyy traces this fault farther to the northeast along the Kukan River.

6. The Khankay-Yalutszyan fault follows the eastern fringe of the Nadan'khada-Alin' Mesozoic folded zone and passes to the southwest of it. It separates the Vandaashansk and Ussuri-Khankay massifs and, proceeding along the upper course of the Mudan'tszyan River, then follows the Yalutszyan River, reaching the west Korean Gulf.

7. The western Sikhote-Alin' fault (named by N. A. Belyaevskiy [1]) separates the Hercynian and Mesozoic folded zones and runs along the eastern edge of the Ussuri-Khankay massif. The fault apparently extends in a southwesterly direction following the western shore of the Sea of Japan to the city of Wonsan (Korea) and then northeastward to the city of Komsomol'sk.

The northwestern faults cut through the Hercynian folded zone. The series of Girin faults extends from the city of Yantszi northwestward to the Argun' River. The Yantzsi-Fun'khua fault extends along the northern fringe of the shield. The Girin fault, which is a continuation of the former, separates the Panshi-Girin and Chzhanguantsayli structural zones. The Sungari-Nun'tszyan fault bounds the central Sunliao arch on the south and may be traced along the lower reaches of the Sungari and Nun'tszyan Rivers from the city of Girin to the mouth of the Yalukhe. The Yalukhe fault textends along the Yalukhe and the northwestern edge of the Dalaynora basin dividing the Greater Khingan.

North of the Girin faults there is a series of Khankay-Greater Khingan northwesterly and northwest-westerly deep-seated faults (named after the Khanka Lake and the Greater Khingan Range). These faults extend from the city of Mishan' along the Voken' Mesozoic basin to the Ilan' River (Voken' fault), and northwestward from there to the upper reaches of the Nemer River, along the northern edge of the Sunliao basin (Nun'tszyan-Beyan' fault), and west of Nun'tszyan along the Gan'khe (Gan'khe fault). These faults were named after the Voken' and Gan'khe Rivers and the cities of Ilan', Beyan', and Nun'tzsyan).

The series of Amur faults is traceable from the southern fringe of the Amur-Sungari basin to northwestern Greater Khingan. The North-Fen'shuigan sub-latitudinal (SWW) fault passes along the southern edge of the Amur-Sungari basin to the city of Tszyamusy. The Lesser Khingan fault splits the Zeya-Sunliao subsidence area into the Zeya-Bureya and Sunliao block (basins) and is traceable along the Lesser Khingan Range. The Kheykhe-Khuman fault extends along the western boundary of the Zeya-Bureya basin following the Amur River from the city of Khaykhe to a point south of the city of Magdagachi.

These deep-seated faults are identifiable and traceable by the highly varied regional strikes of the structures, by the zones of Mesozoic and Cenozoic effusives, and by the changing facies and thicknesses of the Paleozoic deposits, zones of fracture and folding, the aplitic and pegmatitic zones in the Paleozoic granitoids, the zones of endogenic mineralization, by geomorphological features (trends of ranges, major rivers, the outlines of lowlands, etc.), by geophysical data, etc. The described system of deep-seated faults is responsible for the block (faulted) structure and the metallogeny of the region.

THE PRINCIPAL STRUCTURES

The Proterozoic metamorphic rocks of the shield and of the ancient central massifs in the Hercynian folded zone form linearly-extended structures of the geosynclinal type: anticlinoria and synclinoria. The Lower Proterozoic deposits make up the cores of the anticlinoria, while Upper Proterozoic sediments, inheriting the structural pattern of the Lower Proterozoic structures, comprise the cores of the synclinoria. One distinguishes the Liaotung, An'shan-Khelun (on the shield), Mudan'tszyan, Ilan', Khulin', Dakhechzhene-Iman, the eastern

[4] L.I. Krasnyy traces the fault along the Amur River from Khabarovsk to Komsomol'sk.

and the western Khingan-Bureyan geanticlines, the Dashitszyan-Lin'tszyan (on the shield), Mashan'-Spassk, Fen'shuigan-Tamgin, Khingan-Bureyan synclinoria. Within the shield, between the Liaokhe and Yalutszyan Rivers, the structures can be traced in a sub-latitudinal (NEE) direction. In the Khanka-Yalutszyan fault zone they assume a southeasterly trend. North of the shield the Proterozoic structures form a large sigmoidal fold which is traceable from the Dzhagdy Range along the Bureya Range, Fen'shuigan and Foelin, to the Ussuri-Khanka region. Within the confines of this region it is possible to identify ancient blocks, characterized by a definite strike of the Proterozoic structures. These blocks are bounded by the above mentioned deep-seated faults. The Liaokhe-Yalutszyan shield block displays a northeast — east trend, the Chanbay-Korean block strikes to the southeast, the Vandaashan block has a sublatitudinal trend, the Ussuri-Khanka — southeasterly, the South Primor'ye[5] — southwesterly, the Khungan-Bureya — northeasterly, the Eastern Dzhagdy block — northwesterly, strikes. The corresponding changes in the block-structure strikes coincide with the deep faults which cut them. This permits us to identify the trends of the Proterozoic structures in the ancient sunken blocks as northwest and sublatitudinal in the southeastern part of the Sunliao depression, northeasterly in the Lesser and Greater Khingan, and latitudinally in the northern part of the Zeya-Bureya basin.

The Pre-Sinian granitoids are spatially and structurally related to the Proterozoic deposits which have been considerably assimilated by the former. Abundant in the shield are the Pre-Upper Proterozoic granitoids which have regionally and highly migmatized the Lower Proterozoic deposits. The massifs of the Upper Proterozoic (?), Pre-Sinian granitoids are confined to the margins of the synclinoria. In the Hercynian zone the Pre-Sinian granitoids have, in places, intensively migmatized the Proterozoic deposits and form the core of the Vandaashan' central massif consisting of the major Fen'shuigan, Foelin, and Kentey granitoid intrusions.

As a result of Pre-Sinian folding, two zones having a consolidated basement appeared in the general structure of the region: a) the shield, which represents a zone already considerably consolidated toward the end of the Lower Proterozoic; and b) the northeastern offshoot of the shield, constituting a zone of more recent (Upper Proterozoic) consolidation, having smaller zones stabilized. Regions with varying types of structures can be discerned among the Sinian-Lower Paleozoic formations. On the shield the Sinian-Ordovician weakly folded deposits form relatively large superimposed basins of the platform type. The basins have inherited a number of structural features of the Sinian structures and are elongated along the strike. The trends of the basins in the western part of the Liaokhe-Yalutszyan block are latitudinal and sublatitudinal (NEE), and in the eastern part, northeasterly.

Within the limits of the Bureya-Girin shield offshoot the Sinian-Cambrian folded deposits occur in linearly extended troughs over the ancient rock massifs. To a definite degree the troughs were inherited from the Proterozoic and they make up the cores of the more downwarped parts of the ancient synclinoria. The troughs are developed in the Bureya River basin where they have a southeasterly trend. In the Soviet Lesser Khingan they can be traced in the submeridional (SSW) direction along the right bank of the Amur River, where they plunge under the Mesozoic Amur-Sungari depression and bound the northern fringe of the Vandaashan' massif. South of the city of Tszyamusy in the Vandaashan massif there are no Sinian-Cambrian deposits. Sinian-Cambrian folded structures reappear farther east on the right bank of the Ussuri River and in the Lake Khanka region. Here, like the Proterozoic structures, they have a southeasterly strike. In the vicinity of Spassk, Sinian-Cambrian deposits form a wide synclinoral zone confined to the deepest and the widest part of the Upper Proterozoic synclinorium. Toward the north the zone dips under the Mesozoic Khanka basin and terminates on the southeastern slope of the Vandaashan' massif.

Judging by individual uneroded troughs there was a large sigmoidal fold composed of the Sinian-Cambrian folded structures and the concomitant Caledonian granitoids which are traceable along the trends of the Proterozoic folds from the Dzhagdy Range, the Bureya Range, to the right bank of the Ussuri River.

Sinian-Cambrian structures are also developed under the Mesozoic deposits in the Zeya-Bureya basin. According to A. P. Glushkov, they have southeast (in the northern part of the basin) and southwest (in the southern part) strikes and assume a more and more geosynclinal character toward the southwest. These structures can be traced in a southwesterly direction under the mantle of more recent deposits all the way through the Lesser Khingan and the northwestern part of the Sunliao basin into the area of the Greater Khingan.

It should be noted that the remnants of the granitoid-assimilated Cambrian (?) structures having a sublatitudinal (SWW) strike are identifiable in southern Tsinkheyshan (west of the city of Tszyamusy) at the junction of the

[5]The South-Primor'ye block is located in the Sikhote-Alin' Mesozoic folded zone, where individual outcrops of Proterozoic despoits can be observed.

Khingan-Bureya and Vandaashan' massifs. In the west they abut on the buried Sinian-Cambrian structures of the Sunliao depression.

The Caledonian granitoids which cut the Sinian-Cambrian deposits and are spatially related to them, are widespread in the Khingan-Bureya massif. Here they form large massifs and, together with the ancient granitoids, migmatize the cores of the Pre-Sinian geanticlines. Caledonian granites are to be found also in the Ussuri-Khanka massif.

The Khingan-Bureya, Ussuri-Khanka, and Vandaashan' massifs have undergone subsequent consolidation and expansion as a result of Baykalian-Caledonian folding. The Vandaashan structures were not directly subjected to Baykalian-Caledonian folding.

In the Middle and Upper Paleozoic the difference between the shield structures and the structural features of the Hercynian zone is expressed even more clearly than in the Proterozoic, Sinian, and Lower Paleozoic. Middle Paleozoic deposits are not to be observed in the shield. The moderately developed Upper Paleozoic deposits comprise the local superimposed basins of the platform type. These basins frequently are confined to Sinian-Ordovician troughs. It should be noted that within the limits of the shield the Hercynian, and possibly also Iyenshanian, granitoid masses coincide with the zones of deep-seated northeasterly faults.

In the Hercynian zone Middle and Upper Paleozoic deposits form structures of the geosynclinal and parageosynclinal type, intruded by large massifs of synorogenic Early (Pre-Carboniferous — Permian) and Late-Hercynian granitoids of different phases. It is possible to isolate a number of major structure-facies zones consisting of different complexes of Middle and Upper Paleozoic formations and separated by the reactivated deep-seated faults, primarily of northeasterly and northwesterly trends.

1. The eastern Great-Khingan geanticlinal zone made up of Middle and Upper Paleozoic geosynclinal structures with northeastern strike and the intruding syntectonic Hercynian (primarily Pre-Carboniferous — Permian) granitoids.

2. The western Lesser-Khingan geanticlinal zone is composed of Devonian geosynclinal structures forming wide linear submeridionally (NEE) trending folds. Superimposed upon them are local basins filled with slightly folded Carboniferous-Permian formations. To a considerable extent, these basins have inherited the pattern of Devonian structures. Well developed here are the syntectonic Pre-Carboniferous — Permian granitoids, mostly confined to the cores of major anticlines, and frequently strongly migmatizing the Devonian deposits. The Hercynian folded structures of the western Lesser Khingan underlie the Mesozoic deposits in the Zeya-Bureya depression, exhibiting a different submeridional (NNE)[6] strike in the zone of the Amur (Kheykhe-Khuma) deep-seated fault. In the northern part of the depression (approximately in the region of Mayskoye village) a westerly turn of the Devonian structures is noted. They extend onward to a junction with the latitudinal structures in the northern offshoot of the Mongolian-Okhotsk belt. The remnants of the Devonian folded structures (assimilated by the Early Hercynian granitoids), which in the northern part of the Bureya massif (basins of the Ul'ma, Byssa, and Niman Rivers) have latitudinal and sublatitudinal (SWW) strikes, also belong to this zone.

Along the western edge of the Bureya-Girin uplift from the Amur River along the Tainkheyshan almost to the shield exposure near the city of Dun'khua, lies the large Liaoelin-Tanvankhe geosynclinal zone consisting of Upper Paleozoic structures of the parageosynclinal type and the intruding syntectonic Late Hercynian granitoids. The zone is bounded by the Lesser Khingan, Changdin-Bureya, Khanka-Yalutszyan, Girin, and Chanbay-Blagoveshchensk deep faults, and is characterized by the general submeridional (NNE) strike of the Upper Paleozoic structures. The Hercynian structures lie on the Sinian, and in the northern part also on Caledonian basements. Identifiable in the zone are the Tsinkheyshan', Yuytsyuan', and Chzhanguantsayli structure-facies sub-zones, separated by deep faults and composed of different complexes of rocks and structures. We shall mention only a few of the characteristics of some of the subzones. In the Yuytsyuan' zone the Carboniferous-Permian structures display a northwesterly trend and dip to the west under the Mesozoic-Cenozoic Sunliao depression, in the eastern part of which they exhibit northwesterly, and in the north — submeridional (NNW, NNE) strikes. In relation to the Chzhanguantsayli zone it should be noted that in its southern part the structures have a southwesterly strike.

On the northern slope of the shield is the Girin synclinal zone, separated from the Liaoelin-Tanvankhe geosynclinal zone by the northwestern Erdagou uplift (with outcrops of the Upper-Silurian (?) — Devonian) and by the Girin deep fault. The zone is made up of subplatform Carboniferous (and Lower Carboniferous) and Permian folded structures resting on the Proterozoic basement, outcrops of which also may occur in the northern part of the zone,

[6]According to geophysical data, submeridional (NEE) basement structures may be traced east of Blagoveshchensk under the Mesozoic mantle.

and by the intruding syntectonic Late Hercynian granitoids. The structures show sublatitudinal (NEE) in the southern part, and submeridional (NNW, NNE) strikes, in the northern part, forming a bend bulging toward the east. In the west the zone structures dip under the Mesozoic-Cenozoic formations of the Sunliao basin and join in the southwest with the Middle and Upper Paleozoic subplatform structures of the Kaylu zone on the northern slope of the shield. Farther north, they abut on the Paleozoic geosynclinal structures of the Greater Khingan.

It seems, that the buried subplatform Middle Paleozoic structures are not observable north of the Sungari-Nun'tszyan fault. The Selemdzhi-Liaokhe fault may serve as the easternmost limit of the buried Middle Paleozoic geosynclinal structures of the Greater Khingan.

Structure-facies zones of different ages, developed on the Proterozoic (in the northern part also on the Caledonian) basement, are identifiable along the eastern edge of the Bureya-Girin uplift. Within the Amur-Sungari depression, the Budzhan-Fen'shuygan geosynclinal zone is buried under Mesozoic-Cenozoic deposits. The Middle Devonian subplatform, and Upper Paleozoic parageosynclinal deposits and the intruding Early (Pre-Carboniferous — Permian) and Late-Hercynian granitoids which make up the zone occur on its northern and southern fringes and within the limits of the Kheytszyan uplift, which complicate this zone. The uplift was identified by M. G. Organov and A. M. Smirnov [15, 10]. Northeasterly strikes characterize the zonal structures. South of the Bidzhan-Fan'shuygan zone and as far as the Taypinlin Range, remnants of the Middle-Devonian subplatform structures, almost entirely assimilated by Early-Hercynian granitoids, are to be found at the junction of the Vandaashan and Ussuri-Khanka massifs. They are preserved only in isolated troughs coinciding with the ancient synclinoria (for example, the Kheytay trough) and have a sublatitudinal (SWW) trend.

South of the Vandaashan' massif lies the Tumyn'-Grodekovo geosynclinal zone which may be traced in a southwesterly direction along the Taypinlin Range to the shield. The zone is made up of the folded Upper Paleozoic deposits of the parageosynclinal type and of the intruding Late-Hercynian granitoids.

Identifiable in the zone (from north to south) are the Grodekovo, Taypinlin, and Yanbyan structure-facies sub-zones. The northern and southern sub-zones are characterized by outcrops of the Lower Proterozoic and a shorter Paleozoic sequence. Devonian deposits also occur in the northern zone. The Taypinlin subzone displays thick Upper Paleozoic formations (up to 10 km), partly of volcanic origin.

Distinguishable within the limits of the Hercynian folded zone are areas evidencing previous consolidation characterized by a considerable development of Pre-Carboniferous — Permian granitoids which were not exposed to the strong activity of the late phases of Hercynian folding. They may be found in the Greater Khingan and in the western Lesser Khingan in the area of the Zeya-Bureya basin, in the northern part of the Khingan-Bureya massif, and at the junction of the Vandaashan' and Ussuri-Khanka massifs.

East of the Selemdzhi-Liaokhe fault, including here the Mesozoic folded zone, the Hercynian geosyncline developed on the rigid Proterozoic basement, but in the northern and eastern parts of the Bureya-Girin shield offshoot, in the Mesozoic zone, on the Caledonian basement, and in essence began its development in the Upper Paleozoic (approximately, from the Middle, or perhaps in certain zones, from the end of the Carboniferous). The Middle Paleozoic structures of these regions are of subplatform type, and not infrequently are totally absent.

West of the Selemdzhi-Liaokhe fault the geosynclinal structures developed from the Proterozoic up to the Upper Paleozoic (often only until the beginning, or the middle, of the Carboniferous).

Before the end of the Permian the Dunbey-Priamurian Hercynian folded zone passed into the state of mobile platform and became part of the shield.

Geosynclinal conditions, after the appearance of the Hercynian folding remained only in the northern offshoot of the Mongolian-Okhotsk belt and in the Sikhote-Alin' region, and characterized the platform thus created from north to east.

The Mesozoic (Jurassic and Cretaceous) structures of this platform[7] consist of variably dislocated, continental-lacustrine, and volcanic formations. The degree of dislocation affecting the deposits diminishes primarily in the westerly direction, and in the major basins, also from the edges toward the center.

In the Mesozoic and Cenozoic further differential uplifts and downthrows of the folded basement blocks occurred. These movements began back in the Proterozoic, with the formation of local subsidence blocks of the major troughs which contained slightly folded Mesozoic-Cenozoic, as well as undislocated Cenozoic,

[7]Triassic deposits do not occur in these regions; indications of the existence of a Triassic crust of weathering may be found in A.M. Smirnov's paper [15].

deposits. Along the edges of the Bureya-Girin shield offshoot the Zeya-Bureya, Sunliao (on the western edge), Amur-Sungari, and Khanka (on the eastern edge) major depressions were formed, bounded by deep-seated faults. The Khanka basin, incidentally, formed at the junction of the Vandaashan' and the strongly dislocated Ussuri-Khanka massifs. The Kiaokhe trough was developed transversely to the ancient structures in the southern offshoot of Sunliao depression within the limits of the shield, between the Selemdzhi-Liokhe and Sungari-Liaokhe faults. This trough is filled with a thin formation of Mesozoic deposits deposited on the Proterozoic basement and the Paleozoic platform mantle. Here, one observes a series of local superimposed basins, mostly of graben type, bounded by fractured zones and considerably dislocated Mesozoic formations.

Regularly distributed chains of local basins confined to the edges of ancient structures are developed in the Amur-Sungari interfluve. The northeastern belt encompasses the Sutar, Foshan', Pote, Sindun', Khegan, Shuan'yashan', and Baotsin basins. The sublatitudinal Voken' basin is located in the central zone. The southern belt includes the Mulin, Lin'kow, Ninan', and Dunnin' basins.

A number of local basins are also found in other regions of the Hercynian folded zone and the shield. They coincide where various structures meet and with the zones of deep-seated and other faults (for example, the Yan'tszin', Tszyaokhe, Suyfun basins, chains of minor basins in the shield).

Well developed in the Hercynian folded zone are Mesozoic (Jurassic and Cretaceous, primarily Upper Cretaceous) effusives. Their fields are confined to the zones of the deep-seated faults, whose strikes are predominantly meridional and northeasterly, which were reactivated by the Iyenshanian movements. Effusive fields also may be found in the shield.

The effusives cover vast areas in the Greater Khingan from the Kayluy Mesozoic trough to the Amur River. Two zones of effusives can be identified: a) the central Greater Khingan zone which is traceable in a submeridional (NNE) direction and coincides with a series of meridional and northwesterly-striking deep-seated faults; b) the east Greater Khingan zone confined to the western edge of the Sunliao depression and controlled by the West Sunliao northeasterly striking fault. In the south the latter joins the former.

Further east the effusive fields are much less developed. In the Bureya-Girin uplift and on its slopes one can observe three regional zones of effusives consisting of a number of local fields. The western zone is traceable along the eastern edge of the Sunliao subsidence area. To the north it follows the western fringe of the Zeya-Bureya basin, and in the south it can be observed on the body of the shield (near the city of Fusun). The zone is controlled by the Chanbay-Blagoveshchensk meridional fault, and in the northern part by the Amur (Kheykhe-Khuman) northwesterly-striking fault.

The central zone extends along the Chengdin-Bureya meridional fault from the city of Yan'tszin, and then follows the western slope of the Vandaashan' and Khingan-Bureya massifs. In the central part of the Bureya Range a belt of effusive rocks branches off and stretches along the South Bureya-Liaokhe northwesterly fault from the city of Foshan' to the upper reaches of the Amur and Urmi Rivers.

The eastern zone is located along the Khanka-Yalutszyan northwesterly fault from the city of Bikin to the basin of the Yalutszyan River in the body of the shield.

Extending through the northern part of the Dunbey-Priamurian Hercynian folded zone is the South-Tukuringra-Dzhagdy zone of effusive rocks controlled by the latitudinal fault of the same name.

In several regions of the Hercynian folded zone and the shield situated at the junction of various structures and in the deep-seated fault zones, fields of minor Iyenshanian granite intrusions are associated with the effusive complex. These granitoids are to be found in the Greater and Lesser Khingan, in the Bureya Range, in western Chzdanguantsaylin, and in the region of the city of Yan'tszi. Developed in the Mesozoic folded zone are Triassic folded structures covered by syntectonic intrusive masses, and structures of less folded Upper Jurassic and Cretaceous coal-bearing deposits covered mostly by jointed intrusive formations. The structures of the Sikhote-Alin' geosyncline in the U. S. S. R. are adequately described by P. N. Kropotkin [8], and N. A. Belyayevskiy [1, 2]. In the Chinese part of this region they are developed only in northern Nadan'khada-Alin', where Triassic-Jurassic geosynclinal deposits resting directly upon the Lower Proterozoic, or more precisely, Upper Paleozoic basement, form the Nadan'khada-Alin' geanticline. The geanticlinal structures trend in a southwesterly direction, and then turn toward the southeast. The geanticline separates the Amur-Sungari and Khanka depression and the Bikin synclinal zone filled with Jurassic-Cretaceous deposits. The axial part of the geanticline reveals ultrabasic, basic rocks, and granitoids which cut the Triassic-Jurassic deposits.

As a result of one of the phases of Mesozoic folding manifested at the end of the Jurassic, the Nadan'khada-Alin' zone passed into the

te of "mobile platform" and became a part he Hercynian zone. Differentiated uplifts l subsidences of the basement blocks conled in the Cenozoic with the subsequent fortion of the Mesozoic-Cenozoic major dessions and the positive structural features, ch later served as the basis for the forma- of the main geomorphological features of present topography. Local superimposed ins of the graben type were formed in the ion. They are filled with Tertiary deposits l are confined to the rejuvenated, primarily theasterly trending, deep-seated faults (for mple, Sun'u graben, the basins of the liao graben, developed in the area between cities of Tazyamusy and Sypin).

In the Cenozoic (in Tertiary and Quaternary e) there occurred intensive extrusions of alts associated with major faulting of the ient basement along the reactivated deepited faults. Two major zones of basaltic rusions are to be found: a) the Chanbayanka zone, confined to the Khankautszyan northeasterly trending fault, is ceable almost from the general area of msomol'sk and Bikin across the Chanbayn' and Laoelin basaltic plateau into the in of the Yalutszyan River; b) the 1'shuygan-Khingan zone controlled by the thwest and latitudinal Amurian faults is deoped from the region of the city of Caotsin he western Lesser Khingan. The northsterly trending basalt zone is confined to the t of Mesozoic effusives and is traceable in central part of the Bureya Range from the ur River to the upper reaches of the gun' River.

REFERENCES

Belyayevskiy, N. A., Strukturnyy shov zapnadnogo Sikhote Alinya. [THE STRUCTURAL FRACTURE ZONE OF WESTERN SIKHOTE-ALIN']: Doklady, Akad. Nauk SSSR, t. 77, no. 6, 1951.

Belyayevskiy, N. A., Ocherk geologii Primor'ya. [A GEOLOGICAL OUTLINE OF PRIMOR'YE]: Materialy Vses. n. -i. geol. in-ta, nov. ser, vyp. 1, 1956.

Bogdanov, N. A., Stroyeniye zony glubinnykh razlomov yuzhnogo sklona khrebtov Tukuringra i Dzhagdi. [STRUCTURE OF THE DEEP-SEATED FAULT ZONE ON THE SOUTHERN SLOPE OF TUKURINGRA AND DZHAGDY RANGES]: Byull. Mosk. o-va ispyt. prirody, nov. ser., t. 9, otd. geol., t. 35, vyp. 2, 1960.

Gromov, Yu. A., Tektonika i istoriya formirovaniya Ussuri-Khankayskogo sredinnogo massif. [THE TECTONICS AND HISTORY OF THE FORMATION OF THE USSURI-KHANKAY CENTRAL MASSIF]: Sov. geologiya, no. 12, 1959.

4. E. Liang-tsyun and Yu. A. Khodak, Obshcheye geologicheskoye stroyeniye vostochnoy chasti Malogo Khingana, Loelin'shanya i severnoy chasti Dzhan-Guan-Tsay-linya (SSSR i kNR) i perspektivy poiskov polezhykh iskopayemykh. [THE GENERAL GEOLOGIC STRUCTURE OF THE EASTERN PART OF THE LESSER KHINGAN, LOELIN'SHAN', AND THE NORTHERN PART OF DZHAN-GUAN-TSAY-LIN' (USSR AND THE CHINESE PEOPLE'S REPUBLIC), AND THE PROSPECTS OF EXPLORATION FOR COMMERCIAL MINERALS]: Tr. I ses. Amurskoy i kheyluntszyanskoy kompl. eksped. Akad. Nauk SSSR i Akad. Nauk KNR, 1957.

5. Ivanov, A. Kh., Tektonicheskiye razlomy. [TECTONIC FAULTS]: In the collection, "Geologicheskoye troyeniye Mongol'skoy Narodnoy Respubliki". 1959.

6. Krasnyy, L. I., Mongolo-Okhotskaya geosinklinal'naya oblast' i yeye mesto v strukture Vostochnoy Azii. [THE MONGOLIAN-OKHOTSK GEOSYNCLINAL ZONE AND ITS PLACE IN THE STRUCTURE OF EASTERN ASIA]: Materialy Vses. n. -i. geol. in-ta, vyp., 1, 1958.

7. Krasnyy, L. N., and A. M. Smirnov, Geologo-strukturnaya skhema Dal'nego Vostoka SSSR i sopredel'nykh s yuga territorii. [THE GEOLOGIC STRUCTURAL PATTERN OF THE SOVIET FAR EAST AND THE ADJACENT TERRITORY TO THE SOUTH]: Doklady, Akad. Nauk SSSR, t. 116, no. 3, 1957.

8. Kropotkin, P. N., Kratkiy ocherk tektoniki i paleogeografii yuzhnoy chasti Sovetskogo Dal'nego Vostoka. [A SHORT OUTLINE OF THE TECTONICS AND PALEOGEOGRAPHY OF THE SOUTHERN PART OF THE SOVIET FAR EAST]: In the collection, "Voprosy geologii Azii", t. 1, Izd-vo Akad. Nauk SSSR, 1954.

8a. Krylov, V. A., Geologicheskiye materialy o poleznykh iskopayemykh Malogo Khingana Kitaya. [GEOLOGIC MATERIALS ON THE COMMERCIAL MINERALS OF THE LESSER KHINGAN IN CHINA]: Inst. geologii Akad. Nauk KNR, 1959.

9. Peyve, A. V., Glubinnyye razlomy v geosinklinal'nykh oblastyakh. [DEEP FAULTS IN GEOSYNCLINAL ZONES]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1945.

10. Peyve, A. V., Obshchaya kharakteristika,

klassifikatsiya i prostranstvennoye rospolozheniye glubinnykh razlomor. Glavneyshiye tipy glubinnykh razlomov. [GENERAL CHARACTERISTICS, CLASSIFICATION, AND AREAL DISTRIBUTION OF DEEP FAULTS. THE PRINCIPAL TYPES OF DEEP FAULTS]: St. 1, Izv. Akad. Nauk SSSR, ser. geol., no. 1, 1956.

11. Peyve, A. V., Svyaz' osadkonakopleniya, skladchatosti, magmatizma i mineral'nykh mestorozhdeniy s glubinnymi razlomami. Glavneyshiye tipy glubinnykh razlomov. [THE RELATION OF SEDIMENTATION, FOLDING, MAGMATISM, AND ORE DEPOSITS TO DEEP FAULTS. THE PRINCIPAL TYPES OF DEEP FAULTS]: St. 2. Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1956.

12. Peyve, A. V., and V. M. Sinitsyn, Nekotoryye osnovnyye voprosy ucheniya o geosinklinalyakh. [CERTAIN BASIN PROBLEMS IN STUDYING GEOSYNCLINES]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1950.

13. Sinitzyn, V. M., Osnovnyye cherty tektoniki Kitaya. [THE MAIN FEATURES OF CHINA'S TECTONICS]: In the collection, "Voprosy geologii Azii", t. 2, Izd-vo Akad. Nauk SSSR, 1955.

14. Sinitsyn, V. M., Osnovnyye cherty geologicheskoy struktury Gobi. [THE MAIN FEATURES OF THE GEOLOGIC STRUCTURE OF THE GOBI DESERT]: Byul. Mosk. o-va ispyt. prirody. Otd. geol., t. 31, vyp. 6, 1956.

15. Smirnov, A. M., Osnovnyye voprosy geologii Man'chzhurii. [THE MAIN PROBLEMS OF THE GEOLOGY OF MANCHURIA]: Zap. kharbinskogo ob-va yestest. i etnografov, no. 13, 1954.

16. Sung Shu, and Yu. A. Khodak, Geologicheskiy ocherk khingano-khankayskogo regiona. [A GEOLOGIC OUTLINE OF THE KHINGAN-KHANKAY REGION]: Inst. geologii Akad. Nauk KNR, 1959.

17. Khodak, Yu. A., Geologicheskoye stroyeniye vostochnoy chasti Malogo Khingana, Vandaashanya, severnoy chasti Chzhan-Guan-Tsay-linya (SSSR i KNR) i perspektivy poiskov poleznykh iskopayemykh [THE GEOLOGIC STRUCTURE OF THE EASTERN PART OF THE LESSER KHINGAN, VANDAASHAN', THE NORTHERN PART OF CHZHAN-GUAN-TSAY-LIN' MINERALS. Tr. II ses. Amurskoy i Kheyluntszyanskoy kompl. eksped. Akad. Nauk SSSR, i Akad. Nauk KNR, 1959.

18. Khodak, Yu. A., and Sung Shu, Sopostavleniye drevnikh tolshch. Severo-Vostoka Kitaya i yuga Sovetskogo Dal'nego Vostoka. [COMPARISON OF THE ANCIENT FORMATIONS IN NORTHEASTERN CHINA AND IN THE SOUTHERN PART OF THE SOVIET FAR EAST] Doklady, Akad. Nauk SSSR, t. 128, no. 5 1959.

19. Chang Wen Yu, and M. G. Organov, Osnovnyye cherty geologicheskogo stroyeniya vostochnoy chasti Sungari-Ussuriyskogo geologicheskogo regiona i smezhnoy territorii. [THE MAIN FEATURES OF THE GEOLOGIC STRUCTURE IN THE EASTERN PART OF THE SUNGARI-USSURI GEOLOGIC REGION AND THE ADJACENT TERRITORY]: Tr. III ses. Amurskoy i keyluntszyanskoy kompl. eksped. Akad. Nauk SSSR i Akad. Nauk KNR, 1959.

20. Shatskiy, N. S., et al, Tektonicheskaya karta SSSR. [THE TECTONIC MAP OF THE USSR]: Izd-vo Akad. Nauk SSSR, 1954, 1956.

Council for the Study of Productive Resources, of the State Scientific-Economic Council, of the Council of Ministers of the U. S. S. R., Moscow

Received, 27 December 1960

REVIEWS AND DISCUSSIONS

EFERENCE BOOK FOR INVESTIGATORS OF ORE DEPOSITS[1,2]

by

P. A. Shekhtam

s a result of the extensive development in oviet Union of detailed geologic research the past few decades considerable experi- has accumulated in the study of the struc- s of ore fields and deposits. A large group ologists engaged in this type of studies was ied under the guidance of A. V. Pek and F. I. son at the Institute for the Geology of Ore osits, Petrography, Mineralogy, and Geo- nistry of the U. S. S. R. Academy of Sci- s. This group is cooperating with many ogists belonging to peripheral organizations. reviewed book represents the collective of the investigators of this group, which s with certain general problems of struc- l geology, mainly with the methods of ying the structures of ore fields and de- ts. The second part of the book consists of ketches confined to investigations of ous structural types of deposits.

central position in the first part is occupied discussion of problems arising in large- e geologic mapping as a basic method of ying the structures of ore fields and de- ts. A comprehensive review is provided of ern techniques and methods of compiling de- d geologic plans and maps, including ping based on aerial photography. The section devoted to the methods of rock differentiation is replete with practical suggestions for the successful solution of this problem under particularly difficult conditions. Valuable information is imparted with respect to problems involving the mapping of the folds of intrusive bodies and dikes, stratified intrusives, and effusive rocks. If there is some literature dealing with the mapping of sedimentary and intrusive rocks, the problems associated with mapping effusives is, it seems, elucidated in this book for the first time.

Detailed mapping, as is well known, essentially requires rock-differentiation techniques other than those used in regional mapping. Here, the usual stratigraphic division of sedimentary and effusive complexes, age differentiation of the intrusive rocks, appear to be inadequate. Large scale geologic maps based on this type of differentiation, as a rule, turn out to be lacking in detail and are schematic. This is the reason that it is necessary to apply the lithological, petrographic, and other methods of detailed rock differentiations that are collected and described for the first time in this book.

A very interesting presentation is given of the mapping techniques for particularly complex fold structures. It is to be regretted, however, that this material is treated less systematically than are the subjects dealt with in other sections. More detailed information on the mapping of contact aureoles would have been desirable.

Elucidated in detail are problems of the study and mapping of disjunctive dislocations and their relative age determination. A description is given of the relationship of faults to rock-formations of different age, magmatic bodies, orebodies, and altered zones. The method of fault age determination is discussed, both by comparing sequences of strata developed on both walls, and on the basis of the amount of displacement of non-contemporaneous formations caused by faulting. Abundant original and factual descriptive, and graphic material and geologic maps accompany almost all topics discussed. This is the first time that such a

---

Nastol'naya kniga issledovateley rudnykh mesto- deniy, (pp. 111-112).

Fundamental Problems and Methods of Studying tructures of Ore Fields and Deposits" by a of authors under the guidance of F. I. Vol'fson .I. Lukin. Institute of the Geology of Ore De- s, Petrography, Mineralogy, and Geochemistry U.S.S.R. Academy of Sciences, Gosgeol- zdat, 1960.

systematic and detailed presentation has appeared in print.

A comprehensive description is given of the geologic observations made in fault studies designed to determine the geologic sequence and the direction of movements. Fault striae and grooves, the position of feather joints and fault rock zones, the location of drag fold axial planes, the methods of microstructure analysis, the displacement of characteristic points, the distribution of partial openings, and the distribution of fragments in breccias, are examined.

Along with these materials there is a thorough analysis of geometric displacement. A number of typical problems are solved by descriptive-geometry methods. On the whole, there is little new material here that is not contained in textbooks on mining geometry. The detailed derivations of such commonly used formulas as, for example, that for dips in arbitrarily selected directions (page 192) are in general superfluous. All of these problems can be solved in a simpler, more graphic and accurate way by using the isoline method which is almost unused by the authors. This section is not entirely on a par with the general composition of the book.

The analysis of the correlation of orebodies and the dikes of intrusive rocks is interesting. In examining the main criteria of these relationships (intersections, the presence of fragments of one rock in another, the differences in metamorphism), the authors conclusively demonstrate the weakness and the relative nature of these criteria and the difficulties involved in producing a single-value solution of the problem. The recorded data and a great deal of relevant information published in recent years permit the following single conclusion to be drawn for the time being: many of the described intersections do not contain single-value age proofs. The development of new methods of observation — geochemical, geologic, and others — is apparently required.

A description is given of the procedures to be used in mapping ore deposits under different geologic conditions of emplacement in massive or laminated rocks. Assembled here is the vast material obtained in geological surveys of recent years carried out using all of the modern methods of detailed geological investigations. Unfortunately, those problems which must be solved by orebody mapping applicable to different conditions were not formulated here.

In discussing the use of microstructural analysis to study the structure of ore fields and deposits, the authors have outlined the solutions of the following problems: identification of the genesis of folds, structural investigation of the structure of granite massifs, faulting, the relationship of orebodies to dikes, determination of the origin of fissures, and the relative age of dislocations. Clearly defined is the auxiliary role of the method. A systematic description of microstructural analysis as applied to ore-field structure studies is being published for the first time. This, no doubt, will contribute to a more universal utilization of the method. The simplicity and vividness of the presentation of material and the graphic clarity of the illustrations are noteworthy. It is no secret that many foreign, and our own, manuals on microstructural analysis are written in a very involved style. This fact is partly responsible for the delayed introduction of this method in general practice.

The last chapter contains a description of cases where geophysical methods of investigation may be applied effectively for geologic mapping and structural studies of ore fields. It reveals the potentialities of modern applied geophysics in respect to mapping, tracing out, and delineating geologic formations or tectonic lines; particularly, those not exposed to view. This subject is discussed with adequate detail and ample reference to factual materials. But of far greater significance to ore-field structure studies are geophysical investigations devoted to research dealing with the tectonics of plutonic deposits, the morphological analysis of geologic bodies and surfaces, and the distribution of commercial minerals. These questions have not been reviewed in the book.

The content of the first part of the book treats the fundamental trends and methods of research relative to the structure of ore fields, but does not exhaust the subject matter. To simplify the problem somewhat one might say that a structural study of ore fields, or any other geologic formation, involves two interrelated aspects: historical and morphological. This book treats the historical side of the problem vividly. The work would more appropriately be entitled; "The Methods of Studying the History of the Formation of the Structures of Ore Fields". The author of this review does not wish to detract from the value and significance of this type of research, but it should be stressed that the morphological approach is imperative, especially in connection with the practical utilization of the results obtained in studying the structure of ore fields.

The second part of the book consists of outlines for studying some investigated ore fields and deposits. These descriptions elucidate the results of recent research.

Most of the descriptions are historical in orientation, and not all of them contain enough material on the morphology of ore fields and orebodies. Many original procedural methods

re discussed. The selection of articles, on he whole, is not illustrative of all the sections of the book. There are no references whatsoever to the first part, and there is no organic onnection, therefore, between the two parts of the book.

This brief review of the book reveals the act that it presents a broad and diversified nalysis of the problems relating to studies of he structures of the ore fields. Considerable pace is devoted to the description of original ew methods of geologic investigation and llustrations of their application in terms of ractical examples. All sections are amply upplied with valuable recommendations regarding the best possible conditions required or the application of this or that procedural method.

An important characteristic, persistently eflected throughout the entire work, is the historical approach — an attempt to interpret he geologic structures and forms in terms of heir development. This book stands out avorably among other identical or similar manuals, assuming the character of a monograph. The freshness of the factual material n the geological descriptions and illustrations, the high theoretical level of the discussion, and the simple and lively style of presentation is attractive. The book is written with a great deal of intellectual sophistication.

The appearance of this monograph in substantial measure fills a gap in the literature on the structures of ore fields and the methods of analyzing them, although, of course, it does not exhaust the topics by far, for instance morphologically. It is important that we should have more books devoted to these problems.

Geological circles have long awaited the appearance of such a study, and there is no doubt that it will meet with satisfaction and will become a popular reference book with geologists concerned with ores and other types of deposits. The restricted number of copies published will give the authors the opportunity to prepare a second edition of the monograph in a few years.

Received, 21 March 1961

BIBLIOGRAPHY

GEOLOGICAL LITERATURE RECEIVED AT THE LIBRARY, SECTION OF GEOGRAPHIC-GEOLOGIC SCIENCES, ACADEMY OF SCIENCES, U. S. S. R., JULY 1961

A. Articles in Periodicals

GEOLOGY

1. Akayeva, V. P., O nekotorykh litologicheskikh osobennostyakh kerbonatnykh porod mela severnogo sklona Malogo Kavkaza (mezhdurech'ye Kyurakchaya i Inchachaya). [CERTAIN LITHOLOGICAL CHARACTERISTICS OF CRETACEOUS CARBONATE ROCKS IN THE NORTHERN SLOPE OF THE LESSER CAUCASUS (INTERFLUVE KYURAKCHAY AND INCHACHAY)]: Izv. Akad. Nauk Azerb, SSR, ser. geol.-geogr. nauk i nefti, no. 2.

2. Armand, A. D., Novyye dannyye o poslednem oledenenii na Kol'skom poluostrove. [NEW DATA ON THE LAST GLACIATION ON THE KOLA PENINSULA]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

3. Barabashov, N. P., Ob atmosfere i poverkhnosti Marsa. [ON THE ATMOSPHERE AND THE SURFACE OF MARS]: Izv. Komissii po fizike planet Akad. Nauk SSSR, vyp. 2, 1960.

4. Bekker, Yu. R., Novyye dannyye po stratigrafii devonskikh otlozheniy Yuzhnogo Urala. [NEW DATA ON THE STRATIGRAPHY OF DEVONIAN DEPOSITS IN THE SOUTHERN URALS]: Sov. geol., no. 5.

5. Belokrys, L. S., and V. F. Petrun', O proiskhozhdenii ekzoticheskikh valunov v ponticheskikh otlozheniyakh yuga Ukrainy. [ORIGIN OF THE EXOTIC BOULDERS IN THE PONTIAN DEPOSITS OF THE SOUTHERN UKRAINE]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

6. Belousov, V. V., XII General'naya assambleya Mezhdunarodnogo geodezicheskogo i geoficheskogo soyuza. [THE 12TH GENERAL ASSEMBLY OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION]: Sov. geol., no. 3.

7. Belyayevskiy, N. A., Vengerskiy geologicheskiy institut. [THE HUNGARIAN GEOLOGIC INSTITUTE]: Sov. geol., no. 5.

8. Ber, A. G., O vydelenii antopol'skoy svity miotsena v Belorussii. [IDENTIFICATION OF THE MIOCENE ANTOPOLIAN FORMATION IN BELORUSSIA]: Inform. sb. VSEGEI, no. 43.

9. Bernikov, V. V., Mekhanicheskiy sostav i zasolennost' poverkhnostnykh osadochnykh porod yuzhnoy chasti Omskoy oblasti. [THE MECHANICAL COMPOSITION AND SALINITY OF THE SURFACE SEDIMENTARY ROCKS IN THE SOUTHERN PART OF OMSK OBLAST']: Izv. Omsk. otd. Geogr. o-va Soyuza SSR, vyp. 4(II).

10. Bogush, O. I., and O. V. Yuferev, Sloi s Endothyra communis Karatau i zapadnykh otrogov Talasskogo Alatau. [AN ENDOTHYRA COMMUNIS BED IN THE KARATAU AND THE WESTERN SPURS OF TALASS ALATAU]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

11. Bronguleyev, V. V., Vazhneyshiye cherti stroyeniya osnovnykh geneticheskikh tipov skladchatykh struktur geosinklinal'nykh oblastey. [THE MOST IMPORTANT STRUCTURAL FEATURES OF THE BASIC GENETIC TYPES OF FOLDED STRUCTURES IN GEOSYNCLINAL ZONES]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

12. Bronguleyev, V. V., Osobennosti stroyeniya i vozmozhnyye sposobi obrazovaniya geosinklinal'nykh skladchatykh struktur (na primere Bol'shogo Karatau). [THE STRUCTURAL FEATURES AND THE POSSIBLE METHODS OF FORMATION OF

FOLDED GEOSYNCLINAL STRUCTURES (AS EXEMPLIFIED BY THE GREAT KARATAU)]: Sov. geol., no. 5.

. Bulakh, A. G., Eksplozivnyye brekchii Tur'yego poluostrova i vozrast terskoy svity peshchanikov (Kol'skiy poluostrov). [THE EXPLOSIVE BRECCIA OF THE TURIY PENINSULA AND THE AGE OF THE TEREKAN SANDSTONE FORMATION (KOLA PENINSULA)]: Inform. sb. VSEGEI, no. 43.

. Varsanof'yeva, V. A., O geomorfologicheskom rayonirovaniya territorii Komi ASSR. [ON THE GEOMORPHOLOGICAL DIVISIONS OF THE KOMI REPUBLIC]: Izv. Komi fil. Vses. geogr. o-va, no. 6, 1960.

. Vasil'yev, Yu. M., Khvalynskiye otlozheniya Severnogo Prikaspiya. [THE KHVALYNIAN DEPOSITS IN THE NORTHERN CASPIAN REGION]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

. Vvedenskaya, A. V., Osobennosti napryazhennogo sostoyaniya v ochagakh Pribaykal'skikh zemletryaseniy. [THE STRESSED STATE FEATURES OF THE EARTHQUAKE FOCI OF THE BAYKAL REGION]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

. Viktorov, S. V., Geobotanicheskiye priznaki sovremennoy evolyutsii landshafta pustyni Ustyurt. [THE GEOBOTANICAL INDEXES OF THE MODERN LANDSCAPE EVOLUTION IN THE USTYURT DESERT]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

. Voynovskiy-Kriger, K. G., Silur Lemvinskoy fatsial'n-strukturnoy zony (zapadnyy sklon Polyarnogo Urala). [THE SILURIAN OF THE LEMVINSK STRUCTURE-FACIES ZONE (THE WESTERN SLOPE OF THE POLAR URALS)]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

. Vologdin, A. G., Paleontologicheskoye obosnovaniye vydeleniya siniya v predelakh Vostochnoy Sibiri. [THE PALEONTOLOGICAL BASIS FOR THE IDENTIFICATION OF THE SINIAN WITHIN THE CONFINES OF EASTERN SIBERIA]: Sov. geol., no. 5.

. Ganeshin, G. S., and Yu. F. Chemekov, Pervyy rashirennyy plenum Mezhvedomstvennoy geomorfologicheskoy komissil pri OGGN Akad. Nauk SSSR. [THE FIRST EXPANDED PLENARY SESSION OF THE INTERDEPARTMENTAL GEOMORPHOLOGICAL COMMISSION OF THE DEPARTMENT OF GEOLOGIC AND GEOGRAPHICAL SCIENCES OF THE U. S. S. R. ACADEMY OF SCIENCES]: Sov. geol., no. 3.

21. Gauer, Z. Ye., Litologiya devonskikh otlozheniy yugo-vostochnogo obramleniya Zapadno-Sibirskoy nizmennosti. [THE LITHOLOGY OF THE DEVONIAN OF THE SOUTHEAST BORDERS OF THE WEST SIBERIAN LOWLAND]: Byull. MOIP, otd. geol., t. 66, vyp. 3.

22. Gendler, V. Ye., Dayki aplitov i zhil'nykh granitov Ust'-Belovskogo massiva. [DIKES OF APLITES AND VEINED GRANITES IN THE UST'-BELOVSK MASSIF]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

23. Genkina, R. Z., Mezozoyskaya flora Yuzhno-Yakutskogo (Aldanskogo) kamennougol'nogo basseyna i yeye stratigraficheskoye rasprostraneniye. [THE MESOZOIC FLORA OF THE SOUTH YAKUTIAN COAL BASIN AND ITS STRATIGRAPHIC DISTRIBUTION]: Doklady, Akad. Nauk SSSR, t. 133, no. 3.

24. Gorskiy, V. P., and Ye. A. Grammatchikova, Novyye dannyye po stratigrafii devonskikh otlozheniy kryazha Chernysheva na Pripolyarnom Urale. [NEW DATA ON THE STRATIGRAPHY OF THE DEVONIAN DEPOSITS IN THE CHERNYSHEV RIDGE IN THE POLAR URALS]: Inform. sb. VSEGEI, no. 43.

25. Grosgeym, V. A., and K. F. Korotkova, K voprosu o stroyenii flishevykh ritmov (mnogosloyev). [THE PROBLEM OF THE STRUCTURE OF FLYSCH RHYTHMS (INTERBEDDED LAYERS)]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

26. Devyatkin, Ye. V., N. A. Yefimtsev, Yu. P. Seliverstov, and I. S. Chumakov, O tak nazyvayemykh ledoyemakh Altaya. [ON THE SO-CALLED "ICE-RESERVOIRS" OF OF THE ALTAY]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

27. Devyatkin, Ye. V., Ozernyye basseyny lednikovogo vremeni v Yugo-Vostochnom Altaye. [THE LACUSTRINE BASINS OF THE ICE AGE IN SOUTHEASTERN ALTAY]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

28. Demidov, A. A., Teksturnyye osobennosti porod terrigennoy tolshchi nizhnego karbona Tatarskoy ASSR. [THE TEXTURAL FEATURES OF THE LOWER CARBONIFEROUS TERRIGENEOUS

FORMATIONS IN THE TATAR AUTONOMOUS SOVIET SOCIALIST REPUBLIC]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

29. Demin, A. M., Nekotoryye itogi izucheniya intruzivnykh kompleksov Bol'shogo Kavkaza. [CERTAIN RESULTS OF INVESTIGATIONS OF THE INTRUSIVE COMPLEXES IN THE GREATER CAUCASUS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

30. Dibner, V. D., Neogenovyye otlozheniya na severo-vostoke Zemli Frantsa-Iosifa. [THE NEOGENE DESPOITS IN NORTHWESTERN FRANZ-JOSEF LAND]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

31. Dibner, V. D., Novyye dannyye po paleogeografii antropogena Zemli Frantsa-Iosifa v svete pervykh rezultatov radiokarbonovykh issledovaniy. [NEW DATA ON THE QUATERNARY PALEOGEOGRAPHY OF FRANZ-JOSEF LAND IN THE LIGHT OF THE INITIAL RESULTS OF RADIOCARBON INVESTIGATIONS]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

32. Dobrovol'skiy, V. V., O prirode tak nazyvayemykh "merzlotnykh klin'yev" Kazakhskogo melkosopochnika. [THE NATURE OF THE SO-CALLED, "FROZEN WEDGES" OF THE KAZAKH LOW SOPKA AREA]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

33. Dubinskiy, A. Ya., Zametki o nizhnesredneyurskikh otlozheniyakh Zapadnogo Predkavkaz'ya. [NOTES ON THE LOWER AND MIDDLE JURASSIC DEPOSITS IN WESTERN CISCAUCASIA]: Inform. sb. VSEGEI, no. 43.

34. Dubinskiy, A. Ya., O verkhnepermskikh-nizhnetriasovykh otlozheniyakh Vostochnogo Predkavkaz'ya i Zapadnogo Prikaspiya. [THE UPPER PERMIAN — LOWER TRIASSIC DEPOSITS IN EASTERN CISCAUCASIA AND THE WEST CASPIAN COASTAL REGIONS]: Inform. sb. VSEGEI, no. 43.

35. Yefimova, V. N., K stratigrafii verkhneyurskikh otlozheniy yuzhnoy chasti territorii Kurskoy magnitnoy anomalii. [STRATIGRAPHY OF THE UPPER JURASSIC DEPOSITS IN THE SOUTHERN PART OF THE KURSK MAGNETIC ANOMALY]: Inform. sb. VSEGEI, no. 43.

36. Zhivotovskaya, A. I., and G. F. Shneyder, O vozraste zaunguzskoy svity Turkmenii. [THE AGE OF THE ZAUNGUZIAN FORMATION IN TURKMENIA]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

37. Zonenshayn, L. P., Osobennosti tektonicheskogo razvitiya Zapadnogo Sayana. [THE PECULIARITIES OF TECTONIC DEVELOPMENT IN WESTERN SAYAN]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

38. Zkhus, I. D., Nekotoryye dannyye o znachenii terrigennykh mineralov dlya korrelyatsii geologicheskogo razreza tsentral'nykh oblastey. [CERTAIN DATA ON THE IMPORTANCE OF TERRIGENOUS MINERALS FOR GEOLOGIC SEQUENCE CORRELATION IN THE CENTRAL REGIONS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

39. Ivanov, A. Kh., Tektonika i osnovnyye cherty geologicheskogo razvitiya severo-vostoka Mongolii. [THE TECTONICS AND MAIN FEATURES OF THE GEOLOGIC EVOLUTION IN NORTHEASTERN MONGOLIA]: Sov. geol., no. 5.

40. Ivanov, B. A., Tsentral'nyy Sikhote-Alin'skiy razlom (sdvig). [THE CENTRAL SIKHOTE-ALIN' FAULT (DISPLACEMENT)]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

41. Igolkina, N. S., Dokembriyskiye otlozheniya osadochnogo chekhla na severe Russkoy platformy. [THE PRECAMBRIAN DEPOSITS OF THE SEDIMENTARY MANTLE IN THE NORTH RUSSIAN PLATFORM]: Inform. sb. VSEGEI, no. 43.

42. Il'yin, Ye. A., K kharakteristike geneticheskikh tipov lednikovogo rel'yefa vyurmskoy epokhi na territorii Severo-Zapadnoy Belorussii. [THE CHARACTERISTIC OF THE GENETIC TYPES OF THE GLACIAL RELIEF OF NORTHWESTERN BELORUSSIA]: Doklady, Akad. Nauk BSSR, t. 5, no. 4.

43. Kasatkin, D. P., Struktura platformennogo cherkhla sevèro-vostochnoy Turkmenii. [THE PLATFORM MANTLE STRUCTURE IN NORTHEASTERN TURKMENIA]: Geol. nefti i gaza, no. 5.

44. Kashkay, M. A., Razvitiye geologo-mineralogicheskikh nauk v Sovetskoy Gruzii za 40 let. [THE DEVELOPMENT OF THE GEOLOGIC AND MINERALOGICAL SCIENCES IN SOVIET GEORGIA OVER THE LAST 40 YEARS]: Izv. Akad. Nauk AzerbSSSR, ser. geol.-geogr. nauk i nefti, no. 2.

45. Kirikov, V. P., and I. I. Bykova, Novyye dannyye o geologicheskom stroyenii vostochnoy chasti Pripyatskogo progiba. [NEW DATA ON THE GEOLOGIC STRUCTURE OF THE EASTERN PART OF THE

PRIPYAT' TROUGH]: Inform. sb. VSEGEI, no. 43.

Kirichenko, N. I., K voprosu o drevnikh rechnykh terrasakh na Malom Kavkaze. [THE PROBLEM OF THE ANCIENT RIVER TERRACES IN THE LESSER CAUCASUS]: Izv. Akad. Nauk Azerb-SSSR, ser. geol.-geogr. nauk i nefti, no. 2.

Kleyner, Yu. M., and P. V. Fedorov, O bakinskikh otlozheniyakh predchinkovoy zony Severo-Zapadnogo Ustyurta. [THE BAKUAN DEPOSITS OF THE NEAR-SCARP ("CHINK") ZONE IN NORTH-WESTERN URTYURT]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

Komovskiy, G. F., Termolyuminestsentsiya i vozrast gornykh porod. [THERMO-LUMINESCENCE AND THE AGE OF ROCKS]: Priroda, no. 5.

Konyukhov, I. A., O zavisimosti petrofizicheskikh svoystv terrigennykh porod ot ikh litologii. [DEPENDENCE OF THE PETROPHYSICAL PROPERTIES OF TERRIGENEOUS ROCKS OF THEIR LITHOLOGY]: Vestn. MGU, ser. IV, geol., no. 3.

Kopeliovich, A. V., Epigeneticheskaya al'bitizatsiya plagioklaza v peschanikakh drevnikh tolshch Pridnestrov'ya. [EPIGENETIC ALBITIZATION OF PLAGIOCLASE IN THE SANDSTONES OF THE ANCIENT STRATA IN THE DNESTR RIVER REGIONS]: Byull. MOIP, otd. geol., t. 66, vyp. 3.

Koptev-Dvornikov, V. S., O geologicheskikh usloviyakh razvitiya yavleniy differentsiatsii v granitnykh intruzivakh formatsii malykh glubin. [THE GEOLOGIC DEVELOPMENT CONDITIONS OF THE DIFFERENTIATION PHENOMENA IN GRANITIC INTRUSIVES OF THE SHALLOW-DEPTH TYPE]: Sov. geol., no. 1.

Krasivskaya, I. S., Novyye dannyye po stratigrafii metamorficheskikh slantsev srednego techeniya Malki. [NEW DATA ON THE STRATIGRAPHY OF THE METAMORPHIC SCHISTS IN THE MIDDLE REACHES OF THE MALKA RIVER]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

Krasivskaya, I. S., O sootnoshenii siluriyskikh i podstilayushchikh ikh otlozheniy na Severnom Kavkaze. [THE RELATIONSHIP BETWEEN THE SILURIAN DEPOSITS AND THE SUBJACENT FORMATIONS IN THE NORTHERN CAUCASUS]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

54. Krivskaya, T. Yu., O znachenii skrytykh teksturnykh osobennostey mergel'no-melovykh porod dlya stratigrafii verkhnemelovykh otlozheniy Belorussii. [THE IMPORTANCE OF THE TEXTURAL CHARACTERISTICS OF THE MARLY-CHALK ROCKS TO THE STRATIGRAPHY OF THE UPPER CRETACEOUS DEPOSITS IN BYELORUSSIA]: Inform. sb. VSEGEI, no. 43.

55. Kropotkin, P. N., Paleomagnetizm, paleoklimaty i problema krupnykh gorizontal'nykh dvizheniy zemnoy kory. [PALEOMAGNETISM, PALEOCLIMATES, AND THE PROBLEMS OF THE MAJOR MOVEMENTS OF THE EARTH'S CRUST]: Sov. geol., no. 5.

56. Krymov, V. P., Strukturnyye sootnosheniya tretichnykh i mezozoyskikh otlozheniy Tersko-Sunzhenskoy neftegazonosnoy oblasti. [THE STRUCTURAL RELATIONSHIPS BETWEEN THE TERTIARY AND MESOZOIC DEPOSIT OF THE TEREK-SUNZHA OIL AND GAS DISTRICT]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

57. Kuznetsov, V. A., O vozraste vulkanogenno-osadochnykh tolshch yugo-zapadnogo kryla Kholzunsko-Chuyskogo antiklinoriya Rudnogo Altaya. [THE AGE OF THE VOLCANIC-SEDIMENTARY FORMATIONS ON THE SOUTHWESTERN LIMB OF THE KHOLZUN-CHU GEANTICLINE IN THE RUDNYY ALTAY]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

58. Lazukov, G. I., and V. K. Khlebnikov, O gorizonte tazovskoy moreny v basseyne r. Obi. [THE LEVEL OF THE TAZOVSKAYA MORAINE IN THE BASIN OF THE OB' RIVER]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

59. Lebedeva, N. A., and G. I. Popov, Novyye dannyye o verkhnem pliotsene Kubani. [NEW DATA ON THE UPPER PLIOCENE OF THE KUBAN']: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

60. Leonov, Yu. G., Nizhneyurskiye otlozheniya Severnoy Osetii. [THE LOWER JURASSIC DEPOSITS OF NORTHERN OSETIYA]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

61. Leont'yev, V. M., Korrelyatsiya korbonatnoy tolshchi franskogo yarusa severa Stalingradskoy oblast. [CORRELATION OF THE CARBONATE FORMATION OF THE FRASNIAN STAGE IN NORTHERN STALINGRAD OBLAST']: Geol. nefti i gaza, no. 5.

62. Likharev, B. K., K voprosu o rasprostranenii Productus cancrini vern. v kamskom yaruse Russkoy platformy. [THE PROBLEM OF THE DISTRIBUTION OF PRODUCTUS CANCRINI VERN. IN THE KAMA STAGE OF THE RUSSIAN PLATFORM]: Byull. MOIP, otd. geol., t. 26, vyp. 3.

63. Likharev, B. K., O granitse mezhdu otdelami permi v glavnykh razrezakh Yuzhnoy Yevropy i Yuzhnoy Azii. [THE PERMIAN SERIES AND THE PRINCIPAL SEQUENCES IN SOUTHERN EUROPE AND SOUTHERN ASIA]: Sov. geol., no. 3.

64. Logvinenko, N. V., O flishchevykh teksturakh triasovykh otlozheniy Kryma. [THE FLYSCH TEXTURES OF THE TRIASSIC DEPOSITS IN THE CRIMEA]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

65. Lysenko, M. P., O sostave i svoystvakh lëssovidnykh suglinkov zapadnogo sklona Privolzhskoy vozvyshennosti (na primere lëssovidnykh suglinkov rayona Penzy). [THE COMPOSITION AND PROPERTIES OF THE LOESS-LIKE LOAMS ON THE WESTERN SLOPE OF THE VOLGA UPLAND (AS EXEMPLIFIED BY THE LOESSIAL LOAMS IN THE PENZA REGION)]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

66. L'vova, N. A., Puti izucheniya pervichno-osadochnoy prirody mamskoy tolshchi (dokembriy). [THE METHODS OF STUDYING THE PRIMARY SEDIMENTARY ROCKS OF THE MAMSKAYA FORMATION (PRECAMBRIAN)]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

67. Magnitskiy, V. A., Obolochka i kora Zemli. [THE SHELL AND THE CRUST OF THE EARTH]: Sov. geol., no. 5.

68. Makarychev, G. I., Tektonicheskoye razvitiye khrebta Karatau (Yuzhnyy Kazakhstan) v nizhnem paleozoye. [THE TECTONIC DEVELOPMENT OF THE KARAKAU RANGE (SOUTHERN KAZAKHSTAN) IN THE LOWER PALEOZOIC]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

69. Maksimov, A. V., K voprosu o vozraste lopyanetskoy podsvity Ukrainskikh Karpat. [THE AGE PROBLEM OF THE LOPYANETSKAYA MEMBER IN THE UKRAINIAN CARPATHIANS]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

70. Mamayev, N. F., Morskoy nizhniy kembriy na vostochnom sklone Yuzhnogo Urala. [THE MARINE LOWER CAMBRIAN ON THE EASTERN SLOPE OF THE SOUTHERN URALS]: Sov. geol., no. 5.

71. Masaytis, V. L., Proyavleniya magmatizma na territorii Korei. [MANIFESTATIONS OF MAGMATISM IN KOREA]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

72. Matviyenko, Ye. M., Tektonicheskiye narusheniya tretichnogo perioda na territorii Ukrainskogo kristallicheskogo massiva. [THE TECTONIC DISTURBANCES IN THE TERTIARY PERIOD IN THE AREA OF THE UKRAINIAN CRYSTALLINE MASSIF]: Sov. geol., no. 1.

73. Minskiy, N. A., Intruzivnyye proyavleniya melovogo vozrasta v vostochnoy Gobi. [THE INTRUSIVE MANIFESTATION OF CRETACEOUS AGE IN THE EASTERN GOBI]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

74. Mirchink, M. F., N. A. Krylov, and A. I. Letavin, Verkhnepermsko-nizhnetriasovyye otlozheniya Predkavkazskoy platformy i sopredel'nykh rayonov. [THE UPPER PERMIAN — LOWER TRIASSIC DEPOSITS ON THE CISCAUCASIAN PLATFORM AND THE ADJACENT REGIONS]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

75. Nesvetaylova, N. G., Opyt ispol'zovaniya rastitel'nosti pri kartirovanii dayek i razlomov. [EXPERIENCE IN USING VEGETATION IN MAPPING DIKES AND FAULTS]: Byull. nauchn-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 3.

76. Nikolayev, N. I., Ob ispol'zovanii dannykh noveyshey tektoniki. [THE UTILIZATION OF THE MODERN TECTONIC DATA]: Sov. geol., no. 5.

77. Odintsov, M. M., Novyy yurskiy basseyn na yugo-zapade Sibirskoy platformy. [THE NEW JURASSIC BASIN IN THE SOUTHWEST SIBERIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

78. Popov, Yu. N., Problema retskogo yarusa na severo-vostoke Azii. [THE PROBLEM OF THE RHAETIAN STAGE IN NORTHEASTERN ASIA]: Sov. geol., no. 3.

79. Rastvorova, V. A., Rol'razryvnoy tektoniki v formarovanii rel'yefa Krasnopolyarnskogo rayona Bol'shogo Kavkaza. [THE ROLE OF DISASTROPHISM IN THE FORMATION OF THE RELIEF OF THE KRASNOPOLYANSKIY REGION IN THE GREATER CAUCASUS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

Ronov, A.B., and V.Ye. Khain, Triasovyye litologicheskiye formatsii mira. [THE WORLD'S TRIASSIC LITHOLOGIC FORMATIONS]: Sov. geol., no. 1.

Savarenskiy, Ye.F., and B.N. Shechkov, Stroyeniye zemnoy kory Sibiri i Dal'nego Vostoka po dispersii voln Lyava i Remya. [THE STRUCTURE OF THE EARTH'S CRUST IN SIBERIA AND THE RUSSIAN FAR EAST ACCORDING TO THE DISPERSION OF Q AND R WAVES]: Izv. Akad. Nauk SSSR, ser. geofiz. no. 5.

Slavin, V.I., Stratigraficheskoye polozheniye retskogo yarusa. [THE STRATIGRAPHIC POSITION OF THE RHAETIAN STAGE]: Sov. geol., no. 3.

Sokolov, R.I., and V.K. Rotman, Polozheniye gidrotermal'no-izmenennykh effuzivov v geologicheskoy strukture Tetyukhinskogo rayona. [THE LOCATION OF THE HYDROTHERMALLY-ALTERED EFFUSIVES IN THE GEOLOGIC STRUCTURE OF TETYUKHINSKIY REGION]: Sov. geol., no. 5.

Strelenko, Yu. A., O priznakakh ritmichnosti v sredneyurskikh otlozheniyakh Prikumskoy neftegazonosnoy oblasti. [INDICATIONS OF RHYTHM IN THE MIDDLE JURASSIC DEPOSITS IN THE KUMA OIL AND GAS REGION]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

Stetyukha, Ye.I., and V.T. Pivovarov, O zavisimosti mezhdu fizicheskimi svoystvami glinistykh porod Vostochnogo Predkavkaz'ya. [THE INTERDEPENDENCE OF THE PHYSICAL PROPERTIES OF ARGILLACEOUS ROCKS IN EASTERN CISCAUCASIA]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

Sytinskaya, N.N., Fotometricheskoye i kolorimetricheskoye stravneniye nekotorykh poristykh i plotnykh gornykh porod vulkanicheskogo proiskhozhdeniya s lunnoy poverkhnost'yu. [PHOTOMETRIC AND COLORIMETRIC COMPARISON OF CERTAIN POROUS AND DENSE ROCKS OF VOLCANIC ORIGIN WITH LUNAR SURFACES]: Izv. Komissii po fizike planet Akad. Nauk SSSR, vyp. 2, 1960.

Tagi-zade, P.A., Lorrelyatsiya geologicheskogo rasreza kalinskoy svity mestorozhdeniya Gyurgyany-more. [CORRELATION OF THE GEOLOGIC SEQUENCE OF THE KALIN FORMATION IN GYURGYANY-MORE DEPOSITS]: Az. neft. kh-vo. no. 2.

88. Tairov, Ch. a., K mikrofaunisticheskoy kharakteristike goterivskogo yarusa azerbaydzhanskoy chasti Bol'shogo Kavkaza. [THE MICROFAUNAL CHARACTERISTIC OF THE HAUTERIVIAN STAGE OF THE AZERBAIDZHAN PART OF THE GREATER CAUCASUS]: Az. neft. kh-vo, no. 2.

89. Timergazin, K.R., Otkrytiye siluriyskikh otlozheniy v Bashkirskom Priural'ye. [EXPOSURE OF SILURIAN DEPOSITS IN THE BASHKIRIAN REGION OF THE URALS]: Geol. nefti i gaza, no. 5.

90. Trepetsov, Ye.V., Snezhnaya erosiya v Stepnom Priob'ye. [SNOW EROSION IN THE OB' STEPPE REGIONS]: Byull. nauch.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

91. Trofimov, V.T., and N.P. Bezgin, Nekotoryye dannyye o vyvetrivanii osnovykh effuzivnykh porod. [CERTAIN DATA ON THE WEATHERING OF BASIC EFFUSIVES]: Vestn. MGU, ser. IV, geol., no. 3.

92. Uspenskaya, N.Yu., Poyas krupnykh razlomov v predelakh platform yuga Yevropeyskoy chasti SSSR i Sredney Azii. [THE ZONE OF MAJOR FAULTS WITHIN THE LIMITS OF THE PLATFORMS IN THE SOUTHERN PART OF EUROPEAN USSR AND CENTRAL ASIA]: Sov. geol., no. 3.

93. Ustritskiy, V.I., Osnovnyye etapy evolyutsii morskikh basseynov i fauny brakhiopod Azii v techeniye permskogo perioda. [THE MAIN EVOLUTION STAGES OF MARINE BASINS AND THE BRACHIOPOD FAUNA OF ASIA DURING THE PERMIAN PERIOD]: Sov. geol., no. 1.

94. Fedotov, S.A., et al, Nekotoryye rezul'taty detal'nogo izucheniya seysmichnosti Yuzhnykh Kuril'skikh ostrovov. [CERTAIN RESULTS OF A DETAILED SEISMIC STUDY IN THE SOUTH KURILE ISLANDS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

95. Fialkov, D.N., Ozero Zhalauly. [ZHALAULY LAKE]: Izv. Omsk. otd. Geogr. o-va Soyuza SSSR vyp. 4 (II).

96. Khizanishvili, G.G., Dinamika zemnoy osi vrashcheniya i urovney okeanov. [THE DYNAMICS OF THE EARTH'S AXIS OF ROTATION AND OF OCEAN LEVELS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

97. Khoreva, I.M., and R.Ye. Giterman, Novyye dannyye o raschlenenii tretichnykh

otlozheniy v nizhnem techenii Aldana. [NEW DATA ON THE DIFFERENTIATION OF THE TRIASSIC DEPOSITS IN THE LOWER-COURSE REGIONS OF THE ALDAN]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

98. Tseytlin, S. M., Osobennosti razvitiya pleystotsenovykh oledeneniy na severo-zapade Sibirskoy platformy. [THE DEVELOPMENT PECULIARITIES OF PLEISTOCENE GLACIATIONS IN THE NORTHWESTERN PART OF THE SIBERIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

99. Tsibovskiy, N. I., O vozraste uglenosnykh otlozheniy rayona r. Kubani. [THE AGE OF THE COAL MEASURES IN THE KUBAN' RIVER REGION]: Inform. sb. VSEGEI, no. 43.

100. Chaykovskiy, V. K., Svyaz' endogennogo orudeneniya s magmatizmom v protsesse razvitiya geosinklinaley. [THE ASSOCIATION OF ENDOGENOUS MINERALIZATION WITH MAGMATISM IN THE PROCESS OF GEOSYNCLINAL DEVELOPMENT]: Sov. geol., no. 3.

101. Chebanenko, I. I., O konsolidirovannosti dokembriyskikh massivov. [THE EXTENT OF CONSOLIDATION OF PRECAMBRIAN MASSIFS]: Dopovidi Akad. Nauk UkrSSSR, no. 5.

102. Cheremenskiy, G. A., Vliyaniye skladchatogo fundamenta na teplovoye sostoyaniye mezokaynozoyskikh otlozheniy Zapadno-Sibirskoy nizmennosti. [THE EFFECT OF THE FOLDED BASEMENT ON THE THERMAL STATE OF THE MESOZOIC-CENOZOIC DEPOSITS OF THE WEST SIBERIAN LOWLAND]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

103. Chernikova, Z. A., Senomanskiye trepely Bessarabii. [THE CENOMANIAN DIATOMITES OF BESSARABIA]: Sov. geol., no. 3.

104. Sharanov, V. V., Fotometricheskiye i kolorimetricheskiye sravneniya poverkhnosti Marsa s obraztsami limonita i gornykh porid krasnotsvetnykh tolshch. [PHOTOMETRIC AND COLORIMETRIC COMPARISON OF MARS' SURFACE WITH SAMPLES OF LIMONITE AND RED-BED ROCKS]: Izv. Komissii po fizike planet Akad. Nauk SSSR, vyp. 2, 1960.

105. Shakhsuvarov, T. S., and A. T. Petrosyan, O proiskhozhdenii produktivnoy tolshchi Azerbaydzhana. [ORIGIN OF THE PRODUCING LAYER IN AZERBAYDZHAN]: Doklady, Akad. Nauk AzerbSSSR, t. 17, no. 3.

106. Shevchenko, P. G., Geomorfologicheskoye rayonirovaniye Smolenskoy oblasti. [GEOMORPHOLOGICAL REGIONS OF SMOLENSK OBLAST']: Byull. MOIP, otd. geol., t. 36, vyp. 3.

107. Sheynman, Yu. M., Soobrazheniya o mekanizme zarozhdeniya osnovnykh magm. [CONSIDERATIONS RELATING TO THE GENERATION MECHANISM OF BASIC MAGMAS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

108. Shenkman, Ya. D., Strukturnoye polozheniye i vozrast granitoidov Vostochnoy Tuvy, nesushchikh redkometal'nuyu mineralizatsiyu. [THE STRUCTURAL POSITION AND AGE OF THE EAST TUVA GRANITOIDS SHOWING RARE METAL MINERALIZATION]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

109. Shechkov, B. N., Stroyeniye zemnoy kory v Yevrazii po dispersii poverkhnostnykh voln. [THE EARTH'S CRUSTAL STRUCTURE IN EURASIA ACCORDING TO THE DISPERSION OF SURFACE WAVES]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

110. Shterenberg, L. Ye., O nekotorykh detalyakh protsessa osadochnogo rudoobrazovaniya (na primere margantsevykh rud Vostochnogo Zaural'ya). [CERTAIN DETAILS OF THE PROCESS OF SEDIMENTARY ORE FORMATION (AS EXEMPLIFIED BY THE MANGANESE ORES OF THE WESTERN TRANSURAL REGIONS)]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

111. Yakobson, K. E., K stratigrafii artinskogo yarusa Bel'skoy depressii (Bashkirskoye Predural'ye). [THE STRATIGRAPHY OF THE ARTINSKIAN STAGE IN THE BEL'SKAYA DEPRESSION (THE BASKHIR CIS-URAL REGION)]: Inform. sb. VSEGEI, no. 43.

PALEONTOLOGY

112. Aliyev, O. B., Novyye vidy bryukhonogikh iz verkhemelovykh otlozheniy mezhdurech'ya Koshkarchaya-Terterchaya (Malyy Kavkaz). [NEW TYPES OF GASTROPODS FROM THE UPPER CRETACEOUS DEPOSITS OF THE KOSHKARCHAY-TERTERCHAY INTERFLUVE (LESSER CAUCASUS)]: Izv. Aka Nauk AzerbSSR, ser. geol.-geogr. nauk i nefti, no. 2.

113. Varyukhina, L. M., Spory i pyl'tsa triasovykh otlozheniy yuga Pechorskogo basseyna. [THE SPORES AND POLLEN

OF THE TRIASSIC DEPOSITS IN THE SOUTH PECHORA BASIN]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

4. Guseva, A. N., and S. I. Kulakov, Ob organnicheskom veshchestve porod Ishimskogo shchelochnogo massiva. [THE ORGANIC MATTER IN THE ISHIM ALKALI MASSIF]: Vestn. MGU, ser. IV, geol., no. 3.

5. Davydova, N. N., K kharakteristike diatomovykh vodorosley donnykh otlozheniy Ladozhskogo ozera. [THE NATURE OF THE DIATOM ALGAE OF THE LADOGA LAKE BOTTOMSET BEDS]: Botan. zh. Akad. Nauk SSSR, t. 46, no. 5.

6. Danilova, Ye. I., and V. I. Svistun, O nakhode iskopayemykh kostey cheloveka v allyuvial'nykh otlozheniyakh rayona Dneprodzerzhinskoy GES. [THE DISCOVERY OF FOSILIZED HUMAN BONES IN THE ALLUVIUM IN THE REGION OF THE DNEPRODZERZHINSK HYDROELECTRIC POWER PLANT]: Dopovidi Akad. Nauk URSR, no. 5.

7. Zhuravleva, F. A., O kamernykh otlozheniyakh u nautiloidey i aktinotseratoidey. [THE CAMERAL DEPOSITS IN NAUTILOIDS AND ACTINOCERATOIDS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

8. Zaidova, S. L., Novyy predstavitel' fauny-binagadinskiy ushastyy yezh (Hemiechinus azerbajdzanicus sp. nov.). [A NEW FAUNAL SPECIES — THE BINAGADINIAN EARED URCHIN (HEMIECHINUS AZERBAJDZANICUS SP. NOV.)]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk i nefti, no. 2.

9. Kuptsova, I. A., Diatomovyye vodorosli iz litorinovykh otlozheniy bolota Zavironskiy mokh. [DIATOMACEOUS ALGAE FROM THE LITTORAL DEPOSITS OF THE ZAVIRONSKIY-MOKH SWAMP]: Botan. zh. Akad. Nauk SSSR, t. 46, no. 5.

20. Lipman, R. Kh., Sostav mikrofauny nummulitovykh sloyev mysa Izendy — Aral na severnom beregu Aral'skogo morya. [THE MICROFAUNAL COMPOSITION OF THE CAPE IZENDA-ARAL NUMMULITE BEDS ON THE NORTHERN SHORE OF THE ARAL SEA]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

21. Maslov, V. P., Ne yavlyayutsya li sitsidii i khovanelly utrikulami kharofitov? [DO SICIDIA AND CHOVANELLA REPRESENT THE UTRICLES OF CHAROPHYTES?]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

122. Miklukho-Maklay, A. D., Nekotoryye devonskiye vodorosli Sredney Azii i drugikh oblastey SSSR i ikh porodobrazuyushcheye i paleogeograficheskoye znacheniya. [CERTAIN DEVONIAN ALGAE OF CENTRAL ASIA AND OTHER REGIONS IN THE USSR AND THEIR ROCK-FORMING AND PALEOGEOGRAPHIC SIGNIFICANCE]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

123. Mstislavskiy, M. M., and A. V. Kochenov, Ob usloviyakh obrazovaniya skopleniy ostatkov ryb v maykopskikh otlozheniyakh. [THE ACCUMULATION CONDITIONS OF THE REMAINS OF FISHES IN THE MAYKOP DEPOSITS]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

124. Nevesskaya, L. A., Razvitiye rakoviny nekotorykh vidov dvustvorchatykh mollyuskov v ontogeneze. [THE SHELL DEVELOPMENT OF CERTAIN PHYLA OF BIVALVE MOLLUSCS IN ONTOGENESIS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

125. Popov, K. P., Tertichnyye khvoynyye relikty Kryma i ikh ubezhishcha. [TERTIARY CONIFEROUS REMAINS IN THE CRIMEA AND THEIR SHELTERS]: Botan. zh. Akad. Nauk SSSR, t. 46, no. 5.

126. Rozovskaya, S. Ye., K sistematike semeystva Endothyridae. [THE SYSTEMATIZATION OF THE ENDOTHYRIDAE FAMILY]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

127. Samylina, V. A., Novyye dannyye o nizhnemelovoy flore Yuzhnogo Primor'ya. [NEW DATA ON THE LOWER CRETACEOUS FLORA OF SOUTHERN PRIMOR'YE]: Botan. zh. Akad. Nauk SSSR, t. 46, no. 5.

128. Fonin, V. D., Tertichnyye khvoynyye relikty Kryma i ikh ubezhishcha. [CERTAIN PROBLEMS RELATIVE TO THE MORPHOLOGY OF TENIAL ARCHAEOCYATHEANS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

129. Shvareva, N. Ya., O nakhodkakh Cinnamomum v miotsene Predkarpat'ya. [DISCOVERIES OF CINNAMOMUM IN THE MIOCENE OF THE CISCARPATHIANS]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

130. Shimanskiy, V. N., Spirula i Nautilus kak ob"yekty issledovaniya paleontologa. [SPIRULA AND NAUTILUS AS THE OBJECTS OF A PALEONTOLOGIST'S INVESTIGATION]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

131. Erlanger, A. A., Ob okhrane klassicheskikh mestonakhozhdeniy iskopayemykh ostatkov. [THE CONSERVATION OF THE CLASSIC FOSSIL DEPOSITS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

132. Nikolay Nikolayevich Yakovley, 91 god so dnya rozhdeniya. [NIKOLAY NIKOLAYEVICH YAKOVLEV, 91ST BIRTHDAY ANNIVERSARY]: Sov. geol., no. 3.

133. Yarkin, V. I., and R. K. Makarova, O sluchaye polnoy identichnosti kompleksov vidov mollyuskov iz verkhnego eotsena Prikaspiyskoy nizmennosti i Tsentral'nykh Kyzylkumov. [A CASE OF TOTAL IDENTITY OF COMPLEXES OF MOLLUSK SPECIES FROM THE UPPER EOCENE IN THE CASPIAN LOWLANDS AND THE CENTRAL KYZYLKUM]: Inform. sb. VSEGEI, no. 43.

PETROGRAPHY, MINERALOGY, CRYSTALLOGRAPHY, GEOCHEMISTRY

134. Aleksandrov, S. M., Nekotoryye geokhimicheskiye osobennosti protsessa asharitizatsii magnezial'no-zhelezistykh boratov. [CERTAIN GEOCHEMICAL CHARACTERISTICS OF THE ASCHARITIZATION PROCESS INVOLVING MAGNESIA-IRON BORATES]: Geokhimiya, no. 6.

135. Akhmanova, M. V., and L. L. Leonova, Issledovaniye metamiktnogo raspada tsirkonov s pomoshch'yu infrakrasnykh siyentov pogloshcheniya. [INVESTIGATION OF THE METAMICT DECAY OF ZIRCONS WITH THE AID OF INFRARED ABSORPTION SYENITES]: Geokhimiya, no. 5.

136. Balashov, N. I., Ufertit- novyy mineral iz gruppy davidita. [UFERTITE — A NEW MINERAL OF THE DAVIDITE GROUP]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

137. Belousova, O. N., Petrologiya Tsagan-Oluyevskogo massiva (Vostochnoye Zabaykal'ye). [THE PETROLOGY OF THE TSAGAN-OLUYEVSK MASSIF (EASTERN TRANSBAYKAL)]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

138. Beus, A. A., Raspredeleniye berilliya v granitakh. [DISTRIBUTION OF BERRYLIUM IN GRANITES]: Geokhimiya, no. 5.

139. Blokh, A. M., Redkiye zemli v ostatkakh paleozoyskikh ryb Russkoy platformy. [THE RARE EARTHS IN THE REMAINS OF PALEOZOIC FISH OF THE RUSSIAN PLATFORM]: Geokhimiya, no. 5.

140. Bokiy, G. B., Yu. G. Zagal'skaya, and Ye. A. Pobedimskaya, Kristallokhimiya sul'fidov. [THE CRYSTALLOCHEMISTR OF SULFIDES]: Vestn. MGU, ser. IV, geol., no. 6.

141. Borodin, L. S., and R. L. Barinskiy, O sostave redkikh zemel' v pirokhlorakh iz massivov ul'trassovnykh-shchelochnykh porod i karbonatitov. [THE COMPOSITION OF THE RARE EARTHS IN THE PYROCHLORES FROM THE MASSES OF ULTRABASIC-ALKALINE ROCKS AND CARBONATITES]: Geokhimiya, no. 6.

142. Budnikov, P. P., Perlity. [THE PERLITES Priroda, no. 5.

143. Bursker, Ye. S., B. F. Mitskevich, and K. I. Lazebnik, Germaniy v granitoidakh Ukrainskogo kristallicheskogo shchita. [GERMANIUM IN THE GRANITOIDS OF THE UKRAINIAN CRYSTALLINE SHIELD Geokhimiya, no. 6.

144. Varentsov, I. M., Nekotoryye voprosy geokhimii Usinskogo margantsevogo mestorozhdeniya (Kuznetskiy Alatau). [CERTAIN GEOCHEMICAL PROBLEMS OF THE USINSK MANGANESE DEPOSITS (KUZNETSK ALATAU)]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

145. Varlakov, A. S., K geokhimii bora pri metamorficheskikh protsessakh v svyazi s diabazami na Bakale. [THE GEOCHEMISTRY OF BORON DURING THE METAMORPHIC PROCESSES ASSOCIATE WITH THE DIABASES IN THE BAKAL]: Geokhimiya, no. 6.

146. Vershkovskaya, O. V., and V. S. Saltykova Galliy v porodakh, vmeshchayushchikh flyuoritovo-sul'fidnoye orudeneniye. [GALLIUM IN ROCKS ENCLOSING FLUORITE-SULFIDE MINERALIZATION Geokhimiya, no. 5.

147. Voronich, V. A., Mineraly-zatvornike. [THE HERMIT MINERALS]: Priroda, no. 5.

148. Voskresenskaya, N. T., and Su-Show-'tien K geokhimii shchelochnykh elementov i talliya v mushtinskikh granitakh (Severny Kavkaz). [THE GEOCHEMISTRY OF ALKALINE ELEMENTS AND THALLIUM IN THE MUSHTINSK GRANITES (NORTH CAUCASUS)]: Geokhimiya, no. 6.

149. Ganeyev, I. G., K geokhimii berilliya. [THE GEOCHEMISTRY OF BERYLLIUM Geokhimiya, no. 5.

150. Gel'man, O. Ya., K voprosu primeneniya ob''yemnogo metoda opredeleniya

soderzhaniya radiogennogo argona v mineralakh. [THE PROBLEM OF THE APPLICATION OF THE VOLUMETRIC METHOD IN DETERMINING THE CONTENTS OF RADIOGENIC ARGON IN MINERALS]: Radiokhimiya, t. 3, vyp. 2.

1. Gerasimovskiy, V. I., and V. G. Khitrov, K geokhimii bora v nefelinovykh siyenitakh Lovozerskogo massiva. [THE GEOCHEMISTRY OF BORON IN THE NEPHELINE SYNEITES OF THE LOVOSERSK MASSIF]: Geokhimiya, no. 6.

2. Yemel'yanenko, P. F., K voprosu kaliyevykh polevykh shpatakh v devonskikh granitoidakh Sarysu-Tenizskogo vodorazdela (Tsentral'nyy Kazakhstan). [THE PROBLEM OF THE ORTHOCLASES IN THE DEVONIAN GRANITOIDS OF THE SARYSU-TENIZ DIVIDE (CENTRAL KAZAKHSTAN)]: Vestn. MGU, ser. IV, geol., no. 3.

3. Ivankin, P. F., Problema puchkov malykh intruziy i gidrotermal'nykh strudy na kolchedanno-polimetallicheskikh polyakh Rudnogo Altaya. [THE PROBLEM OF THE BUNDLES OF MINOR INTRUSIONS AND HYDROTHERMAL FLOWS IN THE PYRITIC-POLYMETALLIC FIELDS OF THE RUDYY ALTAY]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

4. Ivanov, I. P., Opyt eksperimental'nogo modelirovaniya al'bitizatsii slyudyanykh slantsev v gidrotermal'nykh usloviyakh. [AN EXPERIMENT IN SIMULATED ALBITIZATION OF MICA SCHISTS UNDER HYDROTHERMAL CONDITIONS]: Byull. nauch. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

5. Zharikov, V. A., Kvartsevo-polevo shpatovyye metasomatity v skarnovykh mestorozhdeniyakh. [QUARTZ-FELDSPAR METASOMATITES IN SKARN-TYPE DEPOSITS]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

6. Kayer, S., Zh. Av'ya, and Zh. Fal'geyrett, Otkrytiye novogo arsenida nikelya v Novoy Kaledonii. [DISCLOSURE OF A NEW NICKEL-ARSENIDE IN NEW CALEDONIA]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

7. Kalenov, A. D., Mezozoyskiye intruzii Vostochnoy Mongolii. [THE MESOZOIC INTRUSIONS OF EASTERN MONGOLIA]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

8. Kozlova, O. G., Goniometriya flogopita Slyudyanki. [GONIOMETRY OF THE SLYUDYANKA PHLOGOPITE]: Vestn. MGU, ser. IV, geol., no. 3.

159. Korzhenevskiy, B. A., O mineralogicheskom sostave porod Karatauskogo kompleksa Mangyshlaka. [THE MINERALOGICAL COMPOSITION OF THE ROCKS IN THE KARATAU COMPLEX OF MANGYSHLAK]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

160. Kosterin, A. V., V. Ye. Kizyura, and V. N. Zuyev, Sootnosheniye redkozemel'nykh elementov v ortitakh nekotorykh izverzhennykh porod Severnoy Kirgizii. [THE RATIO OF RARE-EARTH ELEMENTS IN THE ORTHITES OF CERTAIN IGNEOUS ROCKS IN NORTH KIRGIZIYA]: Geokhimiya, no. 5.

161. Kravchenko, S. M., Petrograficheskiye osobennosti shchelochnogo kompleksa kal'der pro sedaniya Tsentral'nogo Aldana. [THE PETROGRAPHIC CHARACTERISTICS OF THE ALKALINE COMPLEX OF THE SUBSIDENCE CALDERAS IN CENTRAL ALDAN]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

162. Kuznetsov, Ye. A., Ul'traosnovnyye porody r. Dzhusaly (Kazakhstan) i ikh flogopit. [THE ULTRABASIC ROCKS OF THE DZHUSALY RIVER (KAZAKHSTAN) AND THEIR PHLOGOPITES]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

163. Kuz'min, A. M., O sokhrannosti argona v mikrokline. [THE RETENTION OF ARGON IN MICROCLINE]: Geokhimiya, no. 5.

164. Kushev, V. G., Spodumenovyye pegmatity Ukrainy. [THE SPODUMENE PEGMATITES OF THE UKRAINE]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

165. Lukashev, K. I., S. G. Dromashko, and I. A. Dobrovol'skaya, Forma migratsii i kontsentratsii zheleza v lëssovykh porodakh Belorussii. [THE FORM OF MIGRATION AND CONCENTRATION OF IRON IN THE LOESSIAL ROCKS OF BELORUSSIA]: Doklady, Akad. Nauk BellorussSSR, t. 5, no. 5.

166. Lyakhovich, V. V., and R. L. Barinskiy, Osobennosti sostava redkikh zemel' v aktsessornykh mineralakh granitoidov. [A CHARACTERISTIC OF THE RARE-EARTH COMPOSITION IN THE ACESSORY MINERALS OF GRANITOIDS]: Geokhimiya, no. 7.

167. Mamayev, N. F., Novyye dannyye o vozraste giperbazitov na vostochnom sklone Yuzhnogo Urala. [NEW DATA ON

THE AGE OF THE ULTRABASITES ON THE EASTERN SLOPE OF THE SOUTHERN URALS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

168. Manskaya, S. M., T. V. Drozdova, R. P. Kravtsova, and K. I. Tobelko, K biogeokhimii germaniya. [THE BIOGEOCHEMISTRY OF GERMANIUM]: Geokhimiya, no. 5.

169. Malinko, S. V., Endogennyy asharit v kontaktovo-metasomaticheskom mestorozhdenii Urala. [ENDOGENIC ASCHARITE IN THE CONTACT-REPLACEMENT DEPOSITS OF THE URALS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

170. Marakushev, A. A., Faktori mineral'nykh ravnovesiy pri metamorfizme. [FACTORS OF MINERAL EQUILIBRIUM DURING METAMORPHISM]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

171. Marchenko, Ye. Ya., Skapolit iz kontaktovo-metasomaticheskikh obrazovaniy v granitakh Srednego Priazov'ya. [SCAPOLITE FROM CONTACT-METASOMATIC FORMATIONS IN THE GRANITES OF THE CENTRAL PART OF THE AZOV SEA COSTAL REGION]: Dopovidi Akad. Nauk URSR, no. 5.

172. Mogarovskiy, V. V., and L. V. Rosseykin, K geokhimii redkikh i rasseyannykh elementov Maykhurinskogo olovyanno-vol'framovogo mestorozhdeniya (Tsentral'nyy Tadzhikistan). [THE GEOCHEMISTRY OF THE RARE AND DISPERSED ELEMENTS OF THE MAYKHURINSK TIN-TUNGSTEN ORE DEPOSITS (CENTRAL TADZHIKISTAN)]: Geokhimiya, no. 6.

173. Morozov, S. S., and V. A. Selivanov, Sostav i svoystva produktov vyvetrivaniya effuzivnykh porod v usloviyakh tundrovoy zony Severo-Vostoka SSSR. [THE COMPOSITION AND PROPERTIES OF THE PRODUCTS OF EFFUSIVE ROCK WEATHERING UNDER THE CONDITIONS OF THE TUNDRA ZONE IN NORTHEASTERN USSR]: Vestn. MGU, ser. IV. geol., no. 3.

174. Murina, G. A., and V. D. Sprintsson, O sokhrannosti radiogennogo argona v glaukonitakh. [THE RETENTION OF RADIOGENIC ARGON IN GLAUCONITES]: Geokhimiya, no. 5.

175. Myaz', N. I., K voprosu o protsesse perekristallizatsii v khrustalenosnykh kvartsevykh zhilakh. [THE PROBLEM OF THE RECRYSTALLIZATION PROCESS IN CRYSTAL-BEARING QUARTZ VEINS]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

176. Nechayev, Yu. A., Svinets i tsink v medistykh peschanikakh Permskoy oblasti. [LEAD AND ZINC IN THE COPPER SANDSTONES OF THE PERM' REGION]: Geokhimiya, no. 5.

177. Nikolayev, D. S., K. F. Lazarev, and S. M. Grashchenko, Kontsentratsiya izotopov toriya v vodakh Azovskogo morya. [THE CONCENTRATION OF THORIUM ISOTOPES IN THE AZOV SEA WATER]: Doklady, Akad. Nauk SSSR, t. 138, no. 3.

178. Polyakov, A. I., and M. P. Volynets, O raspredelenii toriya v serii ul'traosnovnykh shchelochnykh porod Kol'skogo poluostrova. [THORIUM DISTRIBUTION IN THE SERIES OF ULTRABASIC AND ALKALINE ROCKS OF THE KOLYMA PENINSULA]: Geokhimiya, no. 5.

179. Smolin, P. P., Bezzhelezistyy tal'k. [IRON-FREE TALC]: Prioroda, no. 5.

180. Sobolev, R. N., Geologo-petrograficheskiye osobennosti granitoidov pervogo devonskogo intruzivnogo kompleksa Sarysu-Tenizskogo podnyatiya. [THE GEOLOGIC AND PETROGRAPHIC FEATURES OF THE GRANITOIDS OF THE FIRST DEVONIAN INTRUSIVE COMPLEX IN THE SARYSU-TENIZ UPLIFT]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

181. Stavrov, O. D., K voprosu o soderzhanii redkikh elementov v kvartse. [THE PROBLEM OF THE RARE ELEMENT CONTENT IN QUARTZ]: Geokhimiya, no. 6.

182. Starik, I. Ye., K. F. Lazarev, and Ye. P. Petryayev, K voprosu o forme nakhozhdeniya atomov radioaktivnykh elementov v mineralakh. [THE MODE OF OCCURRENCE OF THE ATOMS OF RADIOACTIVE ELEMENTS IN MINERALS]: Radiokhimiya, t. 3, vyp. 2.

183. Tikhomirov, S. N., O pirofillite v porodakh nizhnego paleozoya i dokembriya(?) v basseyne rr. Malki i Khasauta (Severnyy Kavkaz). [THE PYROPHYLLITE IN THE LOWER PALEOZOIC AND PRECAMBRIAN (?) ROCKS IN THE BASIN OF THE MALKA AND KHASAUT (NORTHERN CAUCASUS)]: Inform. sb. VSEGEI, no. 43.

184. Tugarinov, A. I., Retsenziya na knigu R. D. Rassela i R. M. Farkara "Izotopy

svintsa v geologii". [REVIEW OF R. D. RUSSEL'S AND R. M. FARCAR'S BOOK, "LEAD ISOTOPES IN GEOLOGY"]: Geokhimiya, no. 6.

5. Turskiy, A. A., and V. V. Khokhlov, Spektral'noye opredeleniye sostava granatov i il'menita pri malom kolichestve iskhodnogo veshchestva. [SPECTRAL DETERMINATION OF GARNET AND ILMENITE COMPOSITION USING SMALL QUANTITIES OF THE ORIGINAL SUBSTANCE]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

6. Filatova, L. I., Shchelochnyye amfiboly v komplekse dokembriya Ulutau (Tsentral'nyy Kazakhstan). [THE ALKALINE AMPHIBOLES IN THE PRECAMBRIAN COMPLEX OF THE ULUTAU (CENTRAL KAZAKHSTAN)]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

7. Frank-Kamenetskiy, V. A., and I. Vesel'skiy, Rentgenovskoye issledovaniye izomorfizma v perovskitakh. [X-RAY INVESTIGATION OF ISOMORPHISM IN PEROVSKITES]: Geokhimiya, no. 5.

8. Chepizhnyy, K. I., and T. A. Yakovlevskaya, O bertrandite iz zanoryshey redkometal'nykh pegmatitov. [THE BERTRANDITE FROM THE CAVITIES OF PEGMATITES CONTAINING RARE METALS]: Vestn. MGU, ser. IV, geol., no. 3.

9. Chernitsyn, V. B., and I. I. Sakhatskiy, Sul'fidy svintsa i zheleza v devone yuzhnogo kryla Dneprovo-Donetskoy vpadiny. [LEAD AND IRON SULFIDES IN THE DEVONIAN FORMATIONS OF THE SOUTHERN LIMB OF THE DNEPR-DONETS DEPRESSION]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

90. Chetverikov, S. D., Novyye dannyye srednikh velichin sostavov magmaticheskikh gornykh porod, po S. R. Nokkol'dsu. [NEW DATA ON THE AVERAGE VALUES OF MAGMATIC ROCK COMPOSITION AFTER S. R. NOCKOLDS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

91. Shelkoplyas, V. N., Novyye dannyye o mineralogicheskom sostave chetvertichnykh otlozheniy Srednego Pobuzh'ya. [NEW DATA ON THE MINERALOGICAL COMPOSITION OF THE QUATERNARY DEPOSITS IN THE MIDDLE-COURSE REGION OF THE BUG RIVER]: Dopovidi Akad. Nauk URSR, no. 5.

92. Epshteyn, V. V., Geokhimicheskiy ocherk ozer Solenogo (u d. Klimino) i Gor'kogo (u d. Petrovki) Tyukalinskogo rayona Omskoy oblasti. [A GEOCHEMICAL OUTLINE OF THE SOLENOYE LAKES (NEAR KLIMINO VILLAGE) AND GOR'KOYE (NEAR PETROVKI VILLAGE) IN THE TYUKALINSK DISTRICT OF OMSK OBLAST']: Izv. Omsk. otd. Geogr. o-va Soyuza SSR, vyp. 4 (II).

193. Yashchenko, M. L., E. S. Varshavskaya, and I. M. Gorokhov, Ob anomal'nom izotopnom sostave strontsiya v mineralakh iz metamorfizovannykh porod. [THE ANOMALOUS ISOTOPIC COMPOSITION OF STRONTIUM IN THE MINERALS FROM METAMORPHOSED ZONES]: Geokhimiya, no. 5.

COMMERCIAL MINERALS, AND METHODS OF PROSPECTING AND EXPLORATION

194. Abdullayev, G. K., and A. D. Sultanov, O kollektorskikh svoystvakh porod nizhnego maykopa neftyanogo mestorozhdeniya Amirkhanly. [THE COLLECTING PROPERTIES OF THE LOWER MAYKOP ROCKS IN THE AMIRKHANLY OIL DEPOSITS]: Doklady, Akad. Nauk AzerbSSR, t. 17, no. 3.

195. Amiraslanov, A. A., Geologicheskiye osobennosti otdel'nykh tipov mednykh mestorozhdeniy SSSR i ikh otsenka. [THE GEOLOGIC FEATURES OF THE INDIVIDUAL TYPES OF COPPER DEPOSITS IN THE USSR, AND THEIR EVALUATION]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk i neft, no. 2.

196. Ankudinov, V. N., Opyt primeneniya digrokhimicheskikh issledovaniy v Bachatskom rayone Kuzbassa. [AN EXPERIMENT IN THE USE OF HYDROCHEMICAL RESEARCH METHODS IN THE BACHATSK DISTRICT OF THE KUZNETS BASIN]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

197. Antropov. P. Ya., Mineral'no-syr'yevyye resursy Rumynskoy Narodnoy Respubliki. [THE MINERAL PRODUCTS RESOURCES OF THE RUMANIAN PEOPLES REPUBLIC]: Razv. i okhrana nedr, no. 5.

198. Aristov, V. V., et al, Prognoz struktury nekotorykh mezozoyskikh depressiy Zabaykal'ya i voprosy metodiki poiskov v nikh skrytykh mestorozhdeniy. [STRUCTURAL PROGNOSIS WITH RESPECT TO CERTAIN MESOZOIC DEPRESSIONS IN TRANSBAYKALIA AND THE SELECTION OF THE PROPER TECHNIQUES FOR PROSPECTING ORE DEPOSITS

CONCEALED IN THEM]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

199. Artemov, V. R., and V. Ya. Volochayev, Metodika poiskov i razvedki mestorozhdeniy shchelochnykh amfibolasbestov. [METHODS OF PROSPECTING AND EXPLORATION OF DEPOSITS OF ALKALINE AMPHIBOLE-ASBESTOS]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

200. Belyayevskiy, N. A., Itogi Pervoy Vsesoyuznoy konferentsii po geologii i metallogenii Tikhookeanskogo rudnogo poyasa. [RESULTS OF THE FIRST ALL-UNION CONFERENCE ON THE GEOLOGY AND METALLOGENY OF THE PACIFIC MINERALIZED ZONE]: Sov. geol., no. 1.

201. Belyakova, Ye. Ye., Zakonomernosti vodnoy migratsii medi, svintsa i tsinka i ikh znacheniye dlya poiskovykh tseley. [THE REGULARITIES OF AQUEOUS COPPER, LEAD, AND ZINC MIGRATION AND THEIR SIGNIFICANCE FOR PROSPECTING PURPOSES]: Sov. geol., no. 1.

202. Blum, G., Geokhimicheskiye poiski. [GEOCHEMICAL PROSPECTING]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

203. Bondarenko, V. M., O. A. Demidovich, and A. G. Tarkhov, Pervyye rezul'taty kompleksnogo primeneniya geofizicheskikh metodov dlya pryamykh poiskov mestorozhdeniy almazov v Yakutskoy ASSR. [THE FIRST RESULTS OF THE COMPLEX APPLICATION OF GEOPHYSICAL METHODS IN DIRECT PROSPECTING FOR DIAMOND DEPOSITS IN THE YAKUTIAN AUTONOMOUS SOVIET REPUBLIC]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

204. Bochkarev, V. S., O genezise nefti Chelyabinskogo burougol'nogo basseyna. [THE GENESIS OF PETROLEUM IN THE CHELYABINSK BROWN COAL BASIN]: Geol. nefti i gaza, no. 5.

205. Bulina, L. V., Ob ispol'zovanii materialov aeromagnitnoy s"yemki dlya izucheniya glubinnogo stroyeniya zemnoy kory v predelakh Sibirskoy platformy. [THE UTILIZATION OF AERIAL MAGNETIC SURVEY MATERIALS IN INVESTIGATING THE ABYSSAL STRUCTURE OF THE EARTH'S CRUST WITHIN THE LIMITS OF THE SIBERIAN PLATFORM]: Sov. geol., no. 5.

206. Bukhover, N. A., Osnovnyye bazy mineral'nogo syr'ya kapitalisticheskikh stran. [THE PRINCIPAL CENTERS OF MINERAL RESOURCES IN THE CAPITALISTIC COUNTRIES]: Razv. i okhrana nedr. no. 5.

207. Vakhaniya, Ye. K., Napravleniye i metodika geologorazvedochnykh rabot na neft' i gaz v Gruzii. [THE DIRECTION AND TECHNIQUES OF GEOLOGIC PROSPECTING FOR OIL AND GAS IN GEORGIA]: Sov. geol., no. 1.

208. Vel'kov, A. M., K voprosu o perspektivakh gazoneftenosnosti karbonatnogo devona Saratovskogo Pravoberezh'ya. [THE PROBLEM OF THE PROSPECTIVE GAS AND OIL CONTENT IN THE CARBONACEOUS DEVONIAN FORMATIONS ON THE RIGHT-BANK VOLGA REGIONS OF SARATOV DISTRICT]: Geol. nefti i gaza, no. 5.

209. Vol'fson, N. B., V. G. Gar'kovets, and A. G. Khvalovskiy, Opyt primeneniya geofizicheskikh metodov pri reshenii nekotorykh voprosov glubinnogo geologicheskogo kartirovaniya v Almamykskom rudnom rayone. [EXPERIMENTAL APPLICATION OF GEOPHYSICAL METHODS IN SOLVING CERTAIN PROBLEMS OF SUBSURFACE GEOLOGIC MAPPING IN THE ALMALYK MINING DISTRICT]: Sov. geol., no. 1.

210. Wei Diu-In', and A. A. Saukov, Fiziko-khimicheskiye soobrazheniya o genezise sur'myanykh mestorozhdeniy. [PHYSICO-CHEMICAL CONSIDERATIONS RELATIVE TO THE ORIGIN OF ANTIMONY DEPOSITS]: Geokhimiya, no. 6.

211. Gadzhiyev, R. M., I. S. Gasanov, and N. I. Shapirovskiy, Novaya tekhnika i metodika morskikh gravimetricheskikh issledovaniy. [NEW TECHNIQUES AND METHODS OF MARINE GRAVIMETRIC INVESTIGATIONS]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

212. Ganeyev, I. G., and S. I. Zykov, O drevnem svintsovom orudenenii na territorii Tsentral'nogo Kavkaza. [ANCIENT LEAD MINERALIZATION IN THE TERRITORY OF CENTRAL CAUCASUS]: Sov. geol., no. 1.

213. Ginzburg, A. I., and G. G. Rodionov, O poiskovo-otsenochnykh kriteriyakh na redko- metal'nyye pegmatity, vydvinutykh K. A. Vlasovym. [EXPLORATORY-EVALUATION CRITERIA PROPOSED BY K. A. VLASOV IN PROSPECTING FOR PEGMATITES CONTAINING RARE METALS]: Sov. geol., no. 3.

214. Godlevskiy, M. N., Metallogenicheskiye

provintsii medno-nikelevogo orudeneniya. [THE METALLOGENETIC PROVINCES OF COPPER-NICKEL MINERALIZATION]: Sov. geol., no. 3.

15. Grabovskiy, M. A., O. N. Zherdenko, and Yu. P. Skovorodkin, O vozmozhnosti primeneniya metoda magnitnykh poroshkov pri issledovanii pirrotinovykh rud. [THE POSSIBLE APPLICATION OF THE METHOD OF MAGNETIC POWDERS IN INVESTIGATING PYRRHOTITE ORES]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

16. Grigor'yants, B. V., and V. F. Kireyev, O progrebennykh podnyatiyakh yugo-vostochnoy pribrezhnoy polosy Apsheronskogo poluostrova i perspektivy yeye neftenostnosti. [THE BURIED UPLIFTS OF THE SOUTHEASTERN COASTAL ZONE OF THE APSHERON PENINSULA AND ITS PROSPECTIVE OIL CONTENT]: Az. neft. kh-vo. no. 2.

17. Gurvich, S. I., Novyy titanonosnyy rayon na Ukraine. [THE NEW TITANIUM-BEARING REGION IN THE UKRAINE]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

18. Denisov, M. N., Metod razrabotki ratsional'noy detal'noy razvedki na primere Maslyansloy zony Zyryanovskogo mestorozhdeniya. [A METHOD OF DEVELOPING AN EFFECTIVE DETAILED EXPLORATION PROGRAM AS EXEMPLIFIED IN THE MASLYANSK ZONE OF THE ZYRYANOVSK DEPOSITS]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

19. Denisov, S. A., Iz opyta razvedki medno-molibdenovykh mestorozhdeniy Almalykskogo rayona. [SOME EXPERIENCES IN PROSPECTING COPPER-MOLYBDENUM DEPOSITS IN THE ALMALUK REGION]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

20. Dzherom, S., Metodika issledovaniya bol'shikh ploshchadey. [METHODS OF LARGE-AREA INVESTIGATIONS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

21. Dolitskiy, V. A., and B. M. Yakovlev, Ob ispol'zovanii dannykh elektrokarotazha pri izuchenii oprokinutykh skladok (na primere Kholmskoy Krasnodarskogo kraya). [THE UTILIZATION OF ELECTRICAL-LOGGING DATA IN STUDYING OVERTURNED FOLDS (AS EXEMPLIFIED IN THE KHOLMSKAYA FOLDING OF KRASNODARSKIY KRAY)]: Novosti neft i gazovoy tekhniki, geologiya, no. 4.

222. Dubovskaya, M. V., and M. S. Rozin, Mineral'nyye resursy respubliki Kongo. [THE MINERAL RESOURCES OF THE CONGO REPUBLIC]: Byull. nauchn. - tekh. inform. M-va geol. i okhrany nedr SSSR. no. 3.

223. Dubovskaya, M. V., Mineral'nyye resursy respubliki Kuba. [THE MINERAL RESOURCES OF THE REPUBLIC OF CUBA]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

224. Zoloyev, K. K., Osobennosti geologicheskogo stroyeniya i metody razvedki mestorozhdeniy khrisotil-asbesta. [CHARACTERISTIC GEOLOGIC STRUCTURES OF, AND THE PROSPECTING METHODS USED IN DEPOSITS OF CHRYSOTILE-ASBESTOS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

225. Kogan, I. D., Osnovnyye trebovaniya k geologicheskim otchetam pri utverzhenii zapasov v GKZ. [THE PRINCIPAL REQUIREMENTS TO BE MET BY GEOLOGICAL REPORTS IN FIXING THE RESERVES IN GKZ]: Sov. geol., no. 5.

226. Kosygin, M. K., and G. V. Roslyakov, O rabote V. I. Krasnikova "Osnovy ratsional'noy metodiki poiskov rudnykh mestorozhdeniy". [ON V. I. KRASNIKOV'S PAPER, "THE PRINCIPLES OF EFFECTIVE METHODS OF PROSPECTING FOR ORE DEPOSITS"]: Sov. geol., no. 1.

227. Lapin, S. S., and V. N. Sharapov, O genezise Abakanskogo zhelezorudnogo mestorozhdeniya (Zapadnyy Sayan). [THE GENESIS OF THE ABAKANSK IRON-ORE DEPOSITS (WESTERN SAYAN)]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

228. Pamyati Olega Dmitriyevicha Levitskogo. [IN MEMORIAM OF OLEG DIMITRIYEVICH LEVITSKIY]: Sov. geol., no. 5.

229. Lobanov, I. F., Platina v korennykh porodakh basseyna r. Vilyuy. [PLATINUM IN THE BEDROCK OF THE VILYUY RIVER BASIN]: Sov. geol., no. 5.

230. Mamedov, T. N., O novom tipe rudnykh tel v Belokanskom rayone. [A NEW TYPE OF OREBODIES IN THE BELOKANSK REGION]: Doklady, Akad. Nauk Azerb-SSR, t. 17, no. 3.

231. Mirzoyev, D. A., and M. A. Omarov, Novoye mestprozhdeniye nefti v Dagestane. [A NEW OIL FIELD IN DAGESTAN]:

Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

232. Mikhaylov, A. K., Sistematika geologicheskikh nablyudeniy pri krupnomasshtabnykh s"yemkakh. [SYSTEMATIZATION OF GEOLOGICAL OBSERVATIONS IN LARGE-SCALE SURVEYS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

233. Molchanov, I. I., and A. V. Tyzhnov, Ranniy metamorfizm osadochnykh porod i yego znacheniye dlya poiskov goryuchkikh iskopayemykh. [THE PALEOMORPHISM OF SEDIMENTARY ROCKS AND ITS IMPORTANCE IN THE SEARCH FOR FUELS]: Razv. i okhrana nedr, no. 5.

234. Moskalev, N. P., and V. D. Skaryatin, O mikrotreshchinovatosti karbonatnykh porod v svyazi s ikh neftegazonosnost'yu. [THE MICROSCOPIC JOINTING OF CARBONATE ROCKS IN CONNECTION WITH THEIR OIL AND GAS CAPABILITY]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

235. Mustafabeyli, M. A., G. P. Kornev, and D. M. Akhmedov, Zakonomernosti orudeneniya i genezis Dashkesanskogo zhelezorudnogo mestorozhdeniya. [THE MINERALIZATION MECHANISM AND GENESIS OF THE DASHKESTAN IRON-ORE DEPOSITS]: Sov. geol., no. 5.

236. Neyshtadt, N. M., Poiski pegmatitov pri pomoshchi seysmoelektricheskogo effekta vtorogo roda. [PROSPECTING FOR PEGMATITES WITH THE AID OF A SEISMIC-ELECTRICAL EFFECT OF THE SECOND TYPE]: Sov. geol., no. 1.

237. Nekrasov, I. Ya., I. S. Prozhkov, and A. I. Borodyanskiy, Zolotonosnost' severozapadnoy chasti Verkhoyarno-Chukotskoy skladchatoy oblasti. [THE PRESENCE OF GOLD IN THE NORTHWESTERN PART OF THE VERKHOYANSK-CHUKOTSK FOLDED ZONE]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

238. Novyy sposob geofizicheskoy razvedki poleznykh iskopayemykh. [NEW METHODS OF GEOPHYSICAL SURVEYING FOR COMMERCIAL MINERALS]: Byull. nauchn. -tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

239. Orel, V. Ye., Napravleniye i metodika poiskovykh rabot v Zapadno-Kubanskom progibe. [THE TREND AND METHODS OF PROSPECTING OPERATIONS IN THE WEST KUBAN TROUGH]: Novosti neft. i gazovoy tekhnike, geologiya, no. 4.

240. Ostroumov, F. V., Neytronnyy metod analiza na bor rud skarnovogo tipa. [THE NEUTRON METHOD OF ANALYSIS OF BORON MINERALS OF THE SKARN-TYPE]: Razv. i okhrany nedr, no. 5.

241. Petrova, M. G., and B. N. Korolev, Prognoz struktury nekotorykh mezozoyskikh depressiy Zabaykal'ya i voprosy metodiki poiskov v nikh skrytykh mestorozhdeniy. [PREDICTION AS TO THE STRUCTURE OF CERTAIN MESOZOIC DEPRESSIONS IN TRANSBAYKALIA AND SELECTION OF THE PROPER TECHNIQUES FOR PROSPECTING ORE DEPOSITS CONCEALED IN THEM]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

242. Plotnikov, N. A., Ob osobennostyakh formirovaniya zalezhey nefti v verkhemelovoy izvestiyakhovoy tolshche Karabulak-Achalukskogo i Zamankul'skogo podnyatiy. [THE FORMATIVE CHARACTERISTICS OF OIL DEPOSITS IN THE UPPER CRETACEOUS LIMESTONE BEDS OF THE KARABULAK-ACHALUK AND ZAMANKUL' UPLIFTS]: Novosti neft. i gazovoy tekhnike, geologiya, no. 4.

243. Potapov, S. V., Nizhnekembriyskiye zhelezistyye kvartsity Tuvy. [THE LOWER CAMBRIAN FERRUGINOUS QUARTZITES]: Sov. geol., no. 3.

244. Sopko, P. F., Okolorudnyye izmeneniya v kolchedannykh mestorozhdeniyakh Malogo Kavkaza. [WALL-ROCK ALTERATIONS IN THE PYRITE ORE DEPOSITS OF THE LESSER CAUCASUS]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

245. Tvalchrelidze, G. A., O metodike metallogenicheskogo analiza. [METHOD OF METALLOGENIC ANALYSIS]: Sov. geol., no. 3.

246. Teodorovic, G. I., O knige N. A. Kudryavtseva "Neft', gaz i tverdyye bitumy v izverzhennykh i metamorficheskikh porodakh". [ON N. A. KUDRYAVTSEV'S BOOK: "OIL, GAS, AND SOLID BITUMEN IN IGNEOUS AND METAMORPHIC ROCKS"]: Sov. geol., no. 3.

247. Terent'yev, G. Ye., Retsenziya na knigu A. K. Matveyeva "Geologiya ugol'nykh mestorozhdeniy SSSR". [A REVIEW OF A. K. MATVEYEV'S BOOK, "THE GEOLOGY OF COAL DEPOSITS IN THE USSR"]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

248. Terent'yev, Ye. V., K voprosu o perspektivakh L'vovsko-Volynskogo

kamennougol'nogo basseyna. [ON THE PROSPECTS OF THE L'VOV-VOLYNIA COAL BASIN]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

49. Troshchenko, V. N., Ob assotsiatsii rtutnogo i polimetallicheskogo orudeneniya na primere odnogo iz mestorozhdeniy Yugo-Vostochnogo Altaya. [THE ASSOCIATION OF MERCURY AND POLYMETALLIC MINERALIZATIONS AS EXEMPLIFIED IN ONE OF THE DEPOSITS OF THE SOUTHEASTERN ALTAY]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

50. Tychinskiy, A. A., O roli stratigrafo-litologicheskogo kontrolya v formirovanii polimetallicheskikh mestorozhdeniy Gornogo Altaya. [THE ROLE OF STRATIGRAPHIC-LITHOLOGICAL CONTROL IN THE ORIGINATION OF POLYMETALLIC DEPOSITS IN THE GORNYY ALTAY]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

51. Fedorchuk, V. P., Metodika razvedki rtutno-sus'myanykh mestorozhdeniy. [METHODS OF PROSPECTING FOR MERCURY-ANTIMONY ORE DEPOSITS]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

52. Fil'ko, A. S., M. N. Khulugurov, and S. S. Tentilov, Metodika razvedki shtokverkovykh mestorozhdeniy Dzhidinskogo rudnogo polya. [METHODS OF STOCKWORK EXPLORATION IN THE DZHIDINSK ORE FIELD]: Sov. geol., no. 3.

53. Frolov, N. F., Strukturnyye sootnosheniya noveyshikh tretichnykh i mezozoyskikh otlozheniy s paleozoyskim fundamentom v Prikumskoy neftegazonosnoy oblasti. [THE STRUCTURAL RELATIONSHIPS BETWEEN THE MOST RECENT TERTIARY AND MESOZOIC DEPOSITS AND THE PALEOZOIC BASEMENT IN THE PRIKUMSK OIL- AND GAS-BEARING REGION]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

54. Khat'yanov, F. I., A. V. Amirov, and Z. S. Ivanova, Posloynaya zonal'nost' skorosti seysmicheskikh voln v predelakh nekotorykh neftenosnykh platformennykh struktur Bashkiri. [LIT-PAR-LIT ZONING OF SEISMIC-WAVE VELOCITY WITHIN THE CONFINES OF CERTAIN PETROLIFEROUS PLATFORM-TYPE STRUCTURES OF BASHKIRIA]: Sov. geol., no. 3.

55. Khrebtov, A. I., Resursy podzemnogo tepla Tsentral'nogo Predkavkaz'ya. [THE SUBTERRANEAN THERMAL RESOURCES OF CENTRAL CISCAUCASIS]: Sov. geol., no. 1.

256. Tsimel'zon, I. O., Metod posledovatel'nogo vydeleniya lokal'nykh gravitationnykh anomaliy. [METHOD FOR THE SUCCESSIVE IDENTIFICATION OF LOCAL GRAVITY ANOMALIES]: Novosti neft. i gazovoy tekhniki, geologiya, no. 4.

HYDROGEOLOGY, ENGINEERING GEOLOGY

257. Adadurov, G. A., D. B. Balashov, and A. N. Dermin, Issledovaniye ob"yemnoy szhimayemosti mramora pri vysokikh davleniyakh. [INVESTIGATION OF THE VOLUMETRIC COMPRESSIBILITY OF MARBLE AT HIGH PRESSURES]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

258. Albagachiyeva, V. A., Gidrogeologicheskiye usloviya Kizilkol'skogo mednokolchedannogo mestorozhdeniya. [THE HYDROGEOLOGIC CONDITIONS IN THE KIZILKOL' CHALCOPYRITE DEPOSITS]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

259. Aleksin, A. A., Kondensatisya i peredvizheniye vlagi v pochve i gruntakh v usloviyakh sukhogo klimata. [SOIL AND GROUND MOISTURE CONDENSATION AND MIGRATION IN DRY CLIMATIC CONDITIONS]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

260. Arakelyna, O. I., and A. A. Chistyakova, Rol' i kharakter vody pri issledovanii fazovo-mineralogicheskogo sostava alyumonatriyevogo gidrosilikata. [THE ROLE AND CHARACTER OF WATER DURING THE PHASE AND MINERALOGICAL COMPOSITION ANALYSIS OF SODIUM CIMOLITES]: Tsvetnyye metally, no. 4.

261. Bars, Ye. A., Metody khimicheskogo analiza vod neftyanykh mestorozhdeniy. [METHODS OF CHEMICAL ANALYSIS OF OIL-FIELD WATER]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

262. Biryukov, N. S., Vliyaniye lesa na rēzhim gruntovykh vod. [THE INFLUENCE OF FORESTS ON THE GROUND WATER REGIME]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

263. Bogdanov, G. Ya., Gidrodinamicheskaya zonal'nost' gruntovykh vod severo-zapadnoy chasti Prikaspiyskoy mizmennosti. [HYDRODYNAMIC GROUND WATER ZONATION IN THE NORTHWESTERN PART OF THE CASPIAN

LOWLANDS]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 3.

264. Volarovich, M. P., Issledovaniye fiziko-mekhanicheskikh svoystv gornykh porod pri vysokikh davleniyakh. [INVESTIGATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF ROCKS AT HIGH PRESSURE] Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 4.

265. Vostokova, Ye. A., Fitogennyye bugri-indikatory voskhodyashchikh rodinkov (K voprosu o geograficheskoy zameshchayemosti indikatorov). [PHYTOGENIC MOUNDS AS INDICATORS OF ASCENDING SPRINGS. (THE PROBLEM OF GEOGRAPHICAL REPLACEABILITY OF INDICATORS)]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

266. Gembel', A. V., Mineral'nyye istochniki Valdaya. [THE MINERAL SPRINGS OF VALDAY]: Priroda, no. 5.

267. Golov, A. Ye., N. V. Kolomenskiy, and V. M. Fomin, Itogi Soveshchaniya po metodike inzhenerno-geologicheskogo kartirovaniyastran-chlenov Soveta ekonomicheskoy vzaimopomoshchi (SEV). [THE RESULTS OF THE CONFERENCE ON THE METHODS OF GEOLOGIC-ENGINEERING MAPPING OF THE MEMBER COUNTRIES OF THE COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE (SEV)]: Sov. geol., no. 5.

268. Dmitrovskiy, V., Vozmozhnyye istochniki vodosnabzheniya v pustyne Bet-Pak-Dala. [THE POSSIBLE WATER-SUPPLY SOURCES IN THE BET-PAK-DALA DESERT]: Razv. i okhrana nedr, no. 5.

269. Druzhinin, M. N., Metody izucheniya svoystv gruntov, naxhodyashchikhsya v skrytotekuchem sostoyanii. [METHODS OF STUDYING THE PROPERTIES OF SOIL IN A STATE OF HIDDEN FLOW]: Byull. MOIP, otd. geol., t. 36, vyp. 3.

270. Zhilkin, N. G., and V. I. Morosov, Kharakteristika gornykh porod s pomoshch'yu udel'nogo akusticheskogo soprotivleniya. [CHARACTERISTIC OF ROCKS WITH THE AID OF ACOUSTICAL IMPEDANCE]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

271. Zaytsev, G. N., et al, Novyye predstavleniya ob uglekislyk podzemnykh vodakh rayona Kavkazskikh mineral'nykh vod. [NEW IDEAS ABOUT CARBONIC ACID UNDERGROUND WATER IN THE REGION OF THE CAUCASIAN MINERAL WATERS]: Sov. geol., no. 1.

272. Zatenatskaya, N. P., O svyazi khimicheskogo sostava podzemnykh vod s sostavom porovykh vod glinistykh "vodoupornykh" porod. [THE RELATIONSHIP BETWEEN THE CHEMICAL COMPOSITION OF SUBSURFACE WATER AND THE COMPOSITION OF THE INTERSTITIAL WATER OF ARGILLACEOUS "WATER-RESISTANT" ROCKS]: Doklady, Akad. Nauk SSSR, t. 138, no. 4.

273. Kaplun, V. B., O nekotorykh osobennostyakh raspredeleniya yoda i bora v vodakh produktivnoy tolshchi Bibieybatskogo i Surakhanskogo mestorozhdeniya. [CERTAIN CHARACTERISTICS OF IODINE AND BORON DISTRIBUTION IN THE PRODUCING LAYER WATER IN BIBIEYBATSK AND SURAKHAN DEPOSITS]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. i nefti, no. 2.

274. Kats, D. M., Novyy metod meliorativnoy otsenki rezhima gruntovykh vod. [A NEW METHOD OF GROUND-WATER REGIME EVALUATION FOR RECLAMATION PURPOSES]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

275. Kravchinskiy, Z. Ya., O khimicheskoy kharakteristike vod produktivnoy tolshchi Neftechala. [THE CHEMICAL CHARACTERISTICS OF THE TOP WATER IN THE PRODUCING STRATA OF NEFTECHAL]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 2.

276. Kraynov, S. R., Novyye dannyye o mineral'nykh vodakh Primorskogo kraya. [NEW DATA ON THE MINERAL WATERS IN THE PRIMORSKIY KRAY]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

277. Kuznetsov, A. M., and G. A. Maksimovich, O zakonomernostyakh nekopleniya bromiona v podzemnykh rassolakh. [THE REGULARITIES OF ACCUMULATION OF THE BROMIDE-ION IN SUBSURFACE BRINES]: Doklady, Akad. Nauk SSSR, t. 138, no. 5.

278. Lekhtimyaki, E. V., Primeneniye metoda elektrogidrodinamicheskikh analogii dlya rascheta vodopritokov v otkrytyye vyrabotki Tikhvinskikh boksitovykh mestorozhdeniy. [THE APPLICATION OF THE METHOD OF ELECTRO-HYDRODYNAMIC ANALOGIES FOR OPENCAST WATER INFLOW CALCULATIONS AT THE TIKHVIN BAUXITE DEPOSITS]: Izv. vyssh. uceb. zaved., ser. geol. i razvedka, no. 3.

279. Makkaveyev, A. A., Retsenziya na knigu

G. N. Kamenskogo, M. M. Tolstikhinoy i N. I. Tolstikhina. "Gidrogeologiya SSSR". [A REVIEW OF THE BOOK, "THE HYDROGEOLOGY OF THE USSR", BY G. N. KAMENSKIY, M. M. TOLSTIKHINA, AND N. I. TOLSTIKHIN]: Sov. geol., no. 1.

280. Maruashvili, L. I., Geograficheskiye cherty vysokogornogo karsta Zapadnoy Gruzii. [THE GEOGRAPHIC FEATURES OF WEST GEORGIAN HIGH-MOUNTAIN KARST]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk i nefti, no. 2.

281. Matveyev, N. P., Formirovaniye gidroseti yuzhnoy chasti Moskovskoy oblasti. [THE DRAINAGE PATTERN FORMATION IN THE SOUTHERN PART OF THE MOSCOW OBLAST']: Byull. MOIP, otd. geol., t. 36, vyp. 3.

282. Plotnikov, N. A., Yest' li podzemnyye morya? [DO SUBTERRANEAN SEAS EXIST?]: Priroda, no. 5.

283. Samsonov, F. P., Artezianskiye vody nizhemelovykh otlozheniy Kryma. [THE ARTESIAN WELLS IN THE LOWER CRETACEOUS DEPOSITS OF THE CRIMEA]: Izv. vyssh. ucheb. zaved., ser. geol. i razvedka, no. 2.

284. Suleymanov, D. M., and A. B. Shpikov, Nekotoryye inzhenerno-geologicheskiye svoystva glinistykh otlozheniy apsheronskogo yarusa Bakinskoy bukhty. [SOME ENGINEERING GEOLOGIC CHARACTERISTICS OF THE APSHERONIAN STAGE ARGILLACEOUS DEPOSITS OF THE BAKU BAY]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk i nefti, no. 2.

285. Sultankhodzhayev, A. N., and G. Kh. Khalikov, O vzaimootnosheniyakh oblastey pitaniya, napora i razgruzki podzemnykh vod chetvertichnykh otlozheniy Ferganskoy depressii. [THE INTERRELATIONSHIP OF THE FEEDING, HEAD, AND DISCHARGE ZONES OF SUBSURFACE WATER IN THE QUATERNARY DEPOSITS OF THE FERGANA DEPRESSION]: Doklady, Akad. Nauk UzbekSSR, no. 5.

286. Filatov, K. V., Silikatnyye vody i ikh mesto v gorizontal'noy gidorkhimicheskoy zonal'nosti. [THE SILICATE WATERS AND THEIR PLACE IN HORIZONTAL HYDROCHEMICAL ZONALITY]: Doklady. Akad. Nauk SSSR, t. 138, no. 3.

287. Frolov, A. D., Rasprostraneniye ul'trazvuka v merzlykh pechano-glinistykh porodakh. [ULTRASONIC DISTRIBUTION IN FROZEN SANDY-CLAY ROCKS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 5.

288. Frolov, P. M., Novyye dannyye po gidrogeologii tretichnykh otlozheniy Severnogo Kazakhstana. [NEW DATA ON THE HYDROGEOLOGY OF NORTH KAZAKHSTAN TERTIARY DEPOSITS]: Sov. geol., no. 5.

289. Khalevin, S. G., Kolebaniye urovnya gruntovykh vod v severo-zapadnoy chasti Omska. [THE GROUND-WATER LEVEL VARIATION IN THE NORTHWEST PART OF OMSK]: Izv. Omsk. otd. geogr. o-va Soyuza SSR, vyp. 4 (11).

290. Shavyrina, A. V., O vozmozhnosti prognoza mineralizatsii podzemnykh vod po soderzhaniyu khlora v rasteniyakh-freatofitakh. [THE POSSIBILITY OF PREDICTING THE MINERALIZATION OF SUBTERRANEAN WATER BY THE CONTENTS OF CHLORINE IN PLANT - PHREATOPHYTES]: Sov. geol., no. 3.

291. Shapiro, A. I., Opyt ekspluatatsii podzemnykh vod kontsentrirovannymi vodozaborami. [AN EXPERIENCE IN THE UTILIZATION OF UNDERGROUND WATER BY CONCENTRATED WATER INTAKES]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 3.

292. Shor, G. M., and K. A. Burkov, Nomogramma dlya perescheta rezul'tatov spektral'nogo analiza sukhikh ostatkov vod. [NOMOGRAM FOR CONVERTING THE RESULTS OF THE SPECTRAL ANALYSIS OF THE DRY RESIDUES OF WATER]: Byull. nauchn.-tekh. inform. M-va geol. i okhrany nedr SSSR, no. 2.

B. Papers in "Materialy", "Trudy", "Uchenyye zapiski", and "Sborniki"

1. Byulleten' Komissii po opredeleniyu absolyutnogo vozrasta geologicheskikh formatsiy. [Bulletin of the Commission on the Absolute Age Determination of Geological Formations]: Akad. Nauk SSSR, vyp. 4, M., 1961, 167 pp. Contents: Compilation of the geologic time scale of the USSR expressed in terms of absolute chronology; Kozhina, T. K., Geologic and mineralogical characteristics of the standard sample for methodical ~~re~~ rearch related to absolute age determination; Pekarskaya, T. B., On the scientific research connected with the problem, "Geologic time scale of the USSR, expressed in terms of absolute chronology"; Ivanov, A. I., V. K. Monich, and N. I. Zamyatin, The absolute age of the granitoid intrusions in the southern part of Central Kazakhstan; Firsov, L. V., On the age of the "Vostochnoye" gold ore deposits in connection with the absolute age

determination of the igneous rocks of the Khatynnakh intrusion in the Kolyma basin; Semenenko, N. P., Age determination of the Precambrian metamorphic schists in Sweden by the potassium-argon method; Rubinshteyn, M. M., The formation time of the Caucasian crystalline substratum; Starik, I. Ye., A. Ya. Krylov, and Yu. I. Silin, The absolute age of the basement rocks in the eastern part of the Russian platform; Tugarinov, A. I., and S. I. Zykov, The isotopic composition of lead in the Caucasian and Central Asiatic ore deposits; Bespalova, I. D., and E. I. Semenov, The absolute age of the Lovozersk and other alkaline rock massifs of the Kolyma Peninsula; Firsov, L. V., An experiment in parallel absolute age determination of a rare-metal bearing quartz-feldspthic vien of Ar^{40}, K^{40}, and He^4/Th^{232}; Firsov, L. V., The selection of the decay constant of Potassium-40 for rock age determination on the basis of the Argon-40 to Potassium-40 ratio; Vezerill, G., et al., Potassium-40 decay constant determination by the contents of radiogenic argon in potassic minerals; Brodskiy, A. I., and I. V. Gol'fenfel'd, The reliability of geologic age determination by the method of lead isotopes; Rubinshteyn, M. M., I. G. Grigor'yev, E. D. Uznadze, and O. Ya. Gel'man, Photometric determination of potassium and sodium in ammonium-oxygen flame; Starik, I. Ye., E. V. Sobotovich, and G. P. Lovtsyus, Pyrochemical methods of lead separation from natural compounds; Starik, I. Ye., E. V. Sobotovich, and V. G. Leont'yev, Separation of the chemical forms of lead; Starik, I. Ye., and K. F. Lazarev, Investigation of the adsorption processes developing during leaching; Aleksandruk, V. M., The problem of absolute geologic age determination by the rhenium method; Firsov, L. V., A proposal for a standardized system in publishing materials on absolute age; Starik, I. Ye., N. V. Baranovskaya, V. V. Zhirova, and A. Ya. Krylov, Age determination of magnetites by the helium method; Starik, I. Ye., F. Ye. Starik, and A. N. Elizarova, Comparative leachability of certain isotopes.

2. Voprosy geologii vostochnoy okrainy Russkoy platformy i Yuzhnogo Urala. [Geological Problems of the Eastern Borderland of the Russian Platform and the Southern Urals]: Ufa, 1960, 129 pp. Contents: Olli, A. I., and V. A. Romanov, The Pre-Ordovician history of tectonic development in the Southern Urals; Ovanesov, G. P., New data on the tectonics of Western Bashkiria; Kamaletdinov, M. A., and I. M. Zasyadchuk, The methods of tectonic studies in the Zilair synclinorium in the Southern Urals; Ogarinov, I. S., The problems relating to the nature of the link of the Cisuralian (Perm) trough and the frontal folds of the Urals and the eastern fringe of the Russian platform (within Bashkiria); Khat'yanov, F. I., The structural zoning of the southern part of the Cisuralian trough according to geophysical data; Salikhov, A. G., The main regularities in the distribution of elements in the gravitational field of Tataria and the methods of search for deep structures; Senchenko, G. S., The interrelationship of the reef and conglomeratic facies in the Cis-Ural regions; Olli, A. I., and V. A. Romanov, The comparison of the Pre-Paleozoic deposits of the western slope of the Southern Urals and Ural-Tau mountain Range; Olli, A. I., The age of the Upper Bavlinian deposits of the eastern Russian platform; Klochikhin, A. V., The Ordovician, Silurian, and Lower Devonian on the eastern limb of the Zilair synclinorium in the Southern Urals; Timergazin, K. R., The Upper Tash section of the Silurian Indyatau formations in the Cis-Ural regions; Krauze, S. N., The occurrence and the facies zoning of the Lower Devonian deposits on the western slope of the Southern Urals; Chibrikova, Ye. V., The age of the basaltic beds of the Eifelian stage in Western Bashkiria; Frauze, S. N., and V. A. Maslov, The age of the Tashluian formation in the western slope of the Bashkirian Urals and on the Paleogeography of the Middle Devonian.

3. Materialy VSEGEI. [Materials of the VSEGEI]: nov. ser., vyp. 45. L., 1961. 248 pp. Contents: Bulakh, A. G., The rare metal-bearing ankerite carbonatites of the Sebl'-Yavrsk massif (Kola Peninsula); Vinogradskaya, G. M., Certain veined formations of the Voykar-Syn'insk peridotite massif in the Urals; Kukharenko, A. A., and E. A. Bagdasarov, The Perovskites of the ultrabasic-alkaline rocks of Kola Peninsula; Staritskiy, Yu. G., and Ye. V. Tuganova, The interrelationships of magnetite, ilmenite, and sulfides in the copper-nickel ores in the northwestern part of the Siberian platform; Godlevskiy, M. N., A review of the hypotheses about the origin of sulfide copper-nickel deposits; Rudnik, V. A., The development of the theories on skarn formation; Nefedov, Ye. I., Magnesian oettigite from Yakhimovo; Nefedov, Ye. I., Gerenite - a new mineral; Kazitsyn, Yu. V., Crystallo-optical and X-ray investigation of iriginite; Panov, Ye. N., Cases of regular intergrowth of apatite and biotite in the granitoids of the Olekminsk-Nerchugansk region of Eastern Transbaykalia; Ivanova, V. P., Thermographs of minerals from the oxidized zones of polymetallic deposits;

Kovalev, G. A., Ye. P. Sokolov, and A. I. Komkov, Standard X-ray constants for the principal minerals from the oxidized zones of polymetallic deposits; Kovalev, G. A., and Yu. S. D'yakonov, The classification of clay minerals and the crystalline silicates structurally resembling them; Sokolova, Ye. P., Certain structural and crystallochemical features of the glauconite-group minerals; D'yakonov, Yu. A., Quantitative X-ray analysis of clay-mineral mixtures; Kazitsyn, Yu. V., Reconstruction of IRF-23 apparatus and its adaption for refraction-index measurements of microscopic quantities of immersion liquids for the 1. 780-2. 031 range; Golubkova, L. A., Enrichment of selenium-containing samples for mineralogical analyses; Nefedov, Ye. I., Magnioborite — a new mineral.

4. Materialy po geologii Zapadno-Sibirskoy nizmennosti. [Materials on the Geology of Western Siberian Lowlands]: No. 1, Tomsk, 1961, 109 pp. Contents: Rostovtsev, N. N., The geologic structure and petroliferous potentialities of the west Siberian lowlands; Yushin, V. I., The petroliferous potentialities of the Mezozoic deposits of Tomsk Oblast'; Lebedev, I. V., The Jurassic formations of the Chulymo-Yenisey depression; Greigor'yev, K. N., L. G. Makarov, and Yu. P. Kazanskiy, Stratigraphy of the Upper Cretaceous deposits in the southeastern part of the west Siberian lowlands; Kazanskiy, Yu. P., and L. S. Kropanina, The clay minerals in the Cretaceous deposits of the southeastern part of the west Siberian lowland; Voytsel', Z. A., Ye. A. Ivanova, V. F. Kozyreva, S. A. Klimko, and A. G. Poda, Lithologic and paleontological investigation of the Lower Cretaceous deposits in the eastern part of the west Siberian lowlands; Yankovskiy, V. A., S. I. Gurvich, I. B. Sandanov, and A. S. Stolyarov, The mineralogy of the Paleogene sands of the Tuganian formation.

5. Materialy po geologii i poleznym iskopayemym Buryatskoy ASSR. [Materials on the Geology and Economic Minerals of the Buryat Autonomous Soviet Socialist Republic]: No. 2, Ulan-Ude, 1960, 94 pp. Contents: Arsent'yev, V. P., L. S. Volkov, and T. V. Kopeykina, The interrelationships between the granitoids and ultrabasites of the Urik-Onot-Kitoy interfluve (Eastern Sayan); Garifulin, A. G., The Mesozoic granites of the Vitim upland (Buryat ASSR); Gurulev, S. A., Metamorphism and granites (as exemplified in the Baykal upland); Zagoskin, V. A., The problem of the stage of mineral generation; Yurovskiy, V. N., The problem of the Ungdar Range geomorphology; Fil'ko, A. S., The utilization of mine workings for stockwork prospecting; Saprontseva, A. A., The petrographic characteristic of the coals in certain deposits of the Buryat ASSR; Karabul'kin, A. P., The possible occurrence of Baleyan-type gold in the Borgoysk depression.

6. Meteoritika. [Meteorites]: vyp. 20, M., 1961, 208 pp. Partial contents: Fesenkov, V. G., The nature of the Tunguss meteorite; Kirova, O. A., Mineralogical analysis of soil samples from the landing area of the Tunguss meteorite collected by the 1958 expedition; Starik, I. Ye., et al., The problem of the lead isotope content of iron meteroites; Yavnet', A. A., The dependence of iron meteorite structure on chemical composition and crystallization conditions; Alekseyeva, K. N., and K. A. Tovarenko, The dielectric constant of stony meteorites; Kvasha, L. G., Some new data on the structure of chondrites; Kashkay, M. A., and V. I. Aliyev, The structure and composition of the Yardymlinsk iron meteoritic shower; Yudin, I. A., and N. F. Obotnin, Mineragraphic and X-ray diffraction studies of coal-like chondrites from Migea, Staroye-Boriskino, and Grosznaya; Shaposhnikov, D. P., Studies of the Lipovskiy Khutor meteorite (thesis of a report); Grigor'yev, D. P., V. D. Kolomenskiy, and V. G. Kuznetsova, A compilation of meteorite mineralogy; Vorob'yev, G. G., A method of quantitative spectral analysis of tektites and the silicate phase of meteorites; Kvasha, L. G., and G. S. Gorshkov, Vector diagram of the chemical compositions of tektites and terrestrial lavas; Starik, I. Ye., E. V. Sobotovich, M. M. Shats, and G. P. Lovtsyus, Uranium and lead in tektites.

7. Nauchnyye trudy Nauchno-issledovatel'skogo gornogo-metallurgicheskogo instituta. [Transactions of the Mining and Metallurgical Scientific Research Institute]: vyp. 1, Yerevan, 1960, 279 pp. Partial contents: Vartapetyan, B. S., Structural control of endogenic mineralization in the territory of the Armenian Soviet Socialist Republic; Leye, Yu. A., Primary dispersion haloes of the copper and polymetallic deposits of the Kafansk ore field; Balasanyan, S. I., and G. Ye. Kochinyan, The problem of the genetic connection of mineralization with the intrusions of northern Armenia.

8. Regional'naya stratigrafiya SSSR. [Regional Stratigraphy of the USSR]: t. 5, M., 1961, 356 pp. Contents: Dalmatskaya, I. I., The stratigraphy and foraminifera of the Middle Carboniferous deposits on the Gor'kiy and Ul'yanovsk Volga

regions; Rauzer-Chernousova, D. M., Middle Carboniferous deposits in the Volga region; Rauzer-Chernousova, D. M., and T. P. Safonova, The stratigraphy of the Middle Carboniferous deposits in the Perm' district of the Kama region; Rauzer-Chernousova, D. M., Biostratigraphic differentiation of the Middle Carboniferous deposits in the Samara meander and the Central Volga regions according to the foraminifera; Fauzer-Chernousova, D. M., Certain Middle Carboniferous fusulinids of the Kama and Volga regions; Reytlinger, Ye. A., The stratigraphy of the Middle Carboniferous deposits in the No. 1 drill core at Krasnaya Polyana in the Central Trans-Volga region; Chernova, Ye. I., Biostratigraphy (forаmininferal) of the Middle Carboniferous deposits on the right bank of the Volga near Saratov; Latskova, V. Ye., I. N. Orlova, Ye. I. Chernova, and D. M. Rauzer-Chernousova, The stratigraphy of the Saratov-district, Trans-Volga Middle Carboniferous deposits; Semikhatova, Ye. N., The importance of foraminifera in stratigraphic studies of the Middle Carboniferous deposits in the zone of the Don-Medvedsk dislocations.

9. Soobshcheniya Moskovskogo otdeleniya Vsesoyuznogo botanicheskogo obshchestvo AN SSSR. [Reports of the Moscow Section of the All-Union Botanical Society of the USSR Academy of Sciences]: M., 1960, 152 pp. Partial contents: Sladkov, A. N., The importance of the comparative morphology of modern plant microspores for spore-pollen analysis; Zaklinskaya, Ye. D., The problem of taxonomy and nomenclature of fossil pollen and spores; Giterman, R. Ye., Holocene vegetation in the lower reaches of the Lena River.

10. Trudy Vsesoyuznogo nauchno-issledovatel'skogo instituta galurgii. [Transactions of the All-Union Scientific Research Institute of Halurgy]: vyp. 40, L., 1960, 447 pp. Contents: Gorbov, A. F., The formation conditions and distribution mechanism of borate deposits of the volcanic-sedimentary type. Voronova, M. L., The petrographic characteristics of the Lower Cambrian salt deposits in the southeastern part of the Siberian platform; Dubinina, V. N., A description of carnallite rocks penetrated by borehole 75 in 1950 in the area of the Solikamsk mines in the Verkhnekamsk deposits; Lobanova, V. V., The petrographic characteristic of the salt formation in the western Azgir uplift; Lobanova, V. V., The petrographic and mineralogical characteristics of the potassium beds in the Zhilyanskoye deposits; Lobanova, V. V., The formation conditions of the sulphate capping bed of the Chelkarsk uplift; Korobov, S. S., Epsomite in the Quaternary deposits of Inder; Korobov, S. S., Some new data on the geology of the Inder uplift; Gerasimova, V. V., Geological and lithological characteristics and depositional conditions of the salt-bearing formation in northwestern Fergana; Korenevskiy, S. M., The element composition of the saliferous, interbedded, and enclosing rocks of the Solotvinsk rock-salt deposits; Pastukhova, M. V., The element composition of the saliferous rocks in the Middle Devonian salt-bearing series in the Tuva autonomous oblast'; Gurevich, V. I., Some characteristics of boron distribution in the sedimentary rocks in the northern part of the Russian platform; Yarzhemskiy, Ya. Ya., The petrography of the Belorussian saliferous deposits; Osinskiy, A. V., A discovery of luneburgite on the Kerch Peninsula; Vakhrameyeva, V. A., and M. L. Voronova, Luneburgite from Kara-Bogaz-Gola and Uzun-Su; Abramova, S. A., and O. F. Marchenko, Materials on the paleontological survey of the subsalt strata in the Kungurskian formations of the Verkhnekamsk potassium deposit; Vakhrameyeva, V. A., and O. P. Gorkun, A petrographic description of the rocks of the subsalt formation and the lower salt beds in the Verkhnekamsk deposits; Gorbov, A. F., The principles of the genetic classification of borates.

11. Trudy Geologicheskogo instituta AN SSSR. [Transactions of the Geological Institute of the USSR Academy of Sciences]: vyp. 18, M., 1961, 150 pp. Contents: Keller, B. M., A general survey of the Tremadoc-stage structure as represented in the most important sections in Europe, Asia, and North America; Keller, B. M., and T. B. Rukavishnikova, The Tremadocian and the adjacent deposits of the Kendyktas Range; Rukavishnikova, T. B., The brachiopods of the Lower Ordovician in the Kendyktas Range; Lisogor, K. A., The trilobites in the Tremadocian and adjacent deposits of Kendyktas; Keller, B. M., and Kh. S. Rozman, The Lower Ordovician deposits in the Aktyubinsk region of Kazakhstan and the adjacent regions in the western slope of the Urals; Balashova, Ye. A., A few Tremadocian trilobites of the Aktubinsk region; Obut, A. M., The graptolites of the Tremadocian and the adjacent deposits in the Aktyubinsk and Orenburg regions.

12. Trudy Gorno-geologicheskogo institute Ural'skogo filiala AN SSSR. [Transactions of the Mining and Geological Institute of the Uralian Branch of the USSR Academy of Sciences]: vyp. 56,

Sverdlovsk, 1961, 163 pp. Contents: Ovchinnikov, L. N., B. A. Yunikov, and L. I. Mettikh, The composition and structure of the hydromicas of the Buldymsk deposit; Bogomolova, L. K., Micas from the reactional zones surrounding the pegmatites in the lode fields of the Central Urals; Yunikov, B. A., L. N. Ovchinnikov, and L. I. Mettikh, The possibility of determining the garnet content of grossular-andradite series by the parameter of the unit cell; Yel'kina, N. T., The zonal density of a garnet crystal; Pokrovskiy, P. V., Stolzite; Svyazhin, N. V., The crystals of ilmenorutile from Mochalin Log in the Central Urals; Chesnokov, B. V., New minerals from the Vishnevyye mountains in the Urals; Avdonin, V. N., Scapolite-syenites of the Uvil'dinsk alkaline zone in the Urals; Avdonin, V. N., Amazonite from the Uvil'dinsk alkaline zone in the Urals; Sherstyuk, A. I., Amazonite and fluorite from the Murzinsk granit massif; Shur, A. S., N. T. Yel'kina, and N. D. Znamenskiy, Ultra- and microporosity of microcline-perthites; Chervyakovskiy, G. F., New associations of hypogenic non-metallic minerals in the ores of the pyrite deposits in the Central Urals; Fominykh, V. G., The discovery of axinite in the Kopansk titanomagnetite deposit in the Southern Urals; Latysh, I. K., and V. G. Fominykh, The character of leaching of ordinary amphiboles in the hornblendites of the Pervoural'sk deposits; Dunayev, V. A., The graphitization of carbonate rocks in the Bakal' deposits; Gladkovskiy, A. K., and I. N. Ushatinskiy, The element composition, origin, and alteration of the Tikhvinskiy region bauxites; Yunikov, B. A., and I. K. Latysh, The solubility of rutile in pseudo-brookite; Yunikov, B. A., An X-ray analysis of the products of vaporous cadmium interaction with galena; Krutsko, N. S., and Yu. S. Solov'yev, The serpentine from the Bazhenovsk asbestos-bearing region as a decorative and industrial stone; Malakhov, A. Ye., and D. I. Bulatov, Separation of Bakal' carbonate ores in a Sonstadt solution by the centrifuge method; Vyalukhin, G. I., and Z. G. Sheina, Swelling as a diagnostic indication in determining the mineral composition of clays; Yershov, V. M., The dot method of determining components under a microscope with the aid of a rotating stage.

Trudy Institute geologii rudnykh mestorozhdeniy, petrografii, mineralogii i geokhimi AN SSSR. [Transactions of the USSR Academy of Science Institute of Geology of Mineral Deposits, Petrography, and Geochemistry]: no. 64, M., 1961, 99 pp. Contents: Nesterova, Yu. A., The methods of chemical analysis of certain sulfide minerals; Senderova, V. M., The methods of chemical analysis of molybdenum-tungsten minerals; Moleva, V. A., The chemical analysis of spinels; Burova, T. A., The chemical analysis of pyrochlore; Vasil'yeva, Z. V., Use of ion-exchange resins for the analysis of apatites; Bogdanova, V. I., G. N. Muravitskaya, and Ye. B. Khalezova, Rare earth element determination in zircons; Danilova, V. V., Qualitative determination of boron in rocks and minerals under field conditions.

14. Trudy Institute mikrobiologii AN SSSR. [Transactions of the Institute of Microbiology of the USSR Academy of Sciences]: vyp. 9, M., 1961, 151 pp. Contents: Kuznetsov, S. I., The principle directions of research into the geologic activity of microorganisms; Messineva, M. A., The geologic activity of bacteria and its effect on geochemical processes; Shturm, L. D., The effects of ecological factors on the microorganisms of petroliferous deposits; Ivanov, M. V., The role of microorganisms in the formation and disintegration of sulfur; Mogilevskiy, G. A., Certain regularities in the distribution of natural gases and microorganisms in a zone of oil and gas deposits; Al'tovskiy, M. Ye., The microflora of underground water and its significance in the formation of natural gases, oil, sulfur, and certain gaseous components; Mektiyeva, V. L., The abundance of microorganisms in present-day and ancient clay-siltstone deposits; Pokrovskiy, V. A., The lower boundary of the biosphere in the territory of the European USSR according to the data of regional geothermal investigations; Andreyevskiy, I. L., The influence of microflora in the third layer of the Yaregsk deposits on the alteration of the composition and properties of oil; Simakova, T. L., et al., The bacterial alteration of petrols and their components in anaerobic conditions; Gurevich, M. S., The role of microorganisms in the formation of underground water chemical composition; Dutova, Ye. N., The significance of sulfate-reducing bacteria for oil prospecting, as exemplified underground-water investigations in Central Asia; Gasenov, M. V., Biogenic reduction of sulfates in layers during sea-water flooding of oil fields; Ashirov, K. B., The life activity of stratal microflora as an indicator of the geologic conditions and processes developing in oil-bearing beds; Sazonova, I. V., The results of studies of the microflora beds of the oil deposits of the Kuybyshev district; Kuznetsova, Z. I., The occurrence and ecology of microorganisms in deep-seated underground water in some territories in the USSR;

Telegina, Z. P., The occurrence and specific composition of bacteria which oxidize the gaseous hydrocarbons in the subterranean waters of the deposits in the Azov-Kuban' depression; Lyalikova, N. N., The role of bacteria in the oxidation of sulfidic ores; Ivanov, V. I., The application of bacterial methods for the enrichment of non-ferrous metals; Karavayko, G. I., Certain problems related to the study of biological sulfate erosion.

15. Trudy Laboratorii geologii uglya AN SSSR. [Transactions of the Coal Geology Laboratory of the USSR Academy of Sciences]: vyp. 11, M.-L., 1961, 454 pp. Contents: Mokrinskiy, V. V., General information on the south Yakutian coal area; Ishina, T. A., The stratigraphy, lithology, and facies of the Jurassic carboniferous deposits of southern Yakutia; Prosviryakova, Z. P., The paleobotanical characteristics of the south Yakutian coal deposits; Val'ts, I. E., The petrographic composition and structure of the coal beds in south Yakutia; Mokrinskiy, V. V., The tectonics of the south Yakutian coal area; Val'ts, I. E., and V. V. Mokrinskiy, The chemical characteristic of south Yakutian coals; Mokrinskiy, V. V., Metamorphism of south Yakutian coals; Mokrinskiy, V. V., Geological estimates of the coal reserves in southern Yakutia; Bogdanova, M. V., The chemical characteristic of the coals in the oxidized zone of the Chul'makan region of the south Yakutia coal field.

16. Trudy Moskovskogo instituta inzhenerov geodezii, aerofotos"yemki i kartografii. [Transactions of the Moscow Institute of Geodetic, Aerial-Survey, and Cartographic Engineers]: vyp. 44, M., 1961, 111 pp. Partial contents: Piotrovskiy, V. V., The problem of the migration of radioactive isotopes and its significance in the development of the lithosphere.

17. Trudy Nauchno-issledovotel'skogo instituta geologyii Arktiki. [Transactions of the Scientific-Research Institute of Arctic Geology]: t. 123, L., 1961, 187 pp. Contents: Vol'nov, D. A., and D. S. Sorokov, The geologic structure of Bennet Island; Vinogradov, V. A., Pre-Upper Paleozoic history of the geologic development of northern Verkhoyn'ye and the northeastern part of the Siberian platform in relation to the area's oil and gas potentialities; Ustritskiy, V. I., The facies zoning of the Middle Paleozoic deposits in Pay-Khoy and the northern part of the Polar Urals; Rogozov, Yu. G., The stratigraphy and paleogeography of the Carboniferous deposits of the Polar Urals in the basin of the middle and upper reaches of the Pechora River; Popov, Yu. N., The Norian deposits in northeastern USSR and the problem of the Rhaetian stage; Nakoryakov, V. D., The problem of the Pre-Mesozoic basement structure of the Yenisey zone of the West Siberian platform; Kochetkov, T. P., The emergenc[e] and development history of the main structural features in North Central Siberia; Gramberg, I. S., M. K. Kalinko, P. S. Puk, and D. S. Sorokov, The future direction of oil prospecting operations in the main potential regions of Northern Siberia; Sorokov, D. S., The oil and gas potentialities of the Leno-Olenek region; Sokolov, V. N., and Yu. N. Kulakov, The utilization of geologic and geomorphologic mapping in the closed regions for oil-prospecting operations; Vener, R. A., and N. N. Urvantzev, The geologic and chemical peculiarities of the Noril'sk coals; Yan, A., Geomorphological investigations of the Polish scientific expedition to Spitsbergen; Vilenskiy, A. M., and V. S. Golubkov, The structure and tectonic control of certain nickel-bearing intrusions in the Kureyka River basin; Goryainov, I. N., The hydrothermal pyrrhotite-chalcopyrite mineralization along the middle reaches of the Avam and Verkhniy Khugdyukant Rivers; Puminov, A. P., and R. V. Fedorova, Peat from the mouth of the Pur River (the northeastern part of the Central Siberian upland); Uspenskiy, A. N., On the contemporary iron conglomerate from the central part of the Koryakskiy Range.

18. Trudy Odesskogo universiteta. [Transactions of the Odessa University]: t. 150, Sbornik stud.rabot, vyp. 6, Odessa, 1960. Partial contents: Kovalevskiy, V. V., Physical-geographical characteristic of the Kuyal'nitskiy deposits; Chepaliga, A. L., The problem of the Lower-Dnyestr terraces.

19. Trudy Sibirskogo nauchno-issledovatel'skog[o] instituta geologii, geofiziki i mineral'nogo syrya (SNIIGGIMS). [Transactions of the Siberian Scientific-Research Institute of Geology, Geophysics, and Mineral Products (SNIIGGIMS)]: M-va geologii i okhrany nedr SSSR, ser. neft. geologiya, vyp. 15, L., 1961, 262 pp. Contents: Teslenko, Yu. V., The Middle Jurassic flora of the west Siberian lowland and its importance for the study of Siberian Jurassic flora; Klimova, I. G., The Upper Jurassic ammonites of the west Siberian lowlands; Putrya, F. S., The miliolides of the Upper Jurassic and Paleogene deposits in the west Siberian lowlands; Markova, L. G., Some new data on the pollen of Brachyphyllum Brongn. and Pagiophyllum Heer; Kondrat'yev, G. K., The spore-pollen spectra of the Middle Jurassic

deposits on the eastern margin of the west Siberian lowland; Vekshina, V. N., A new phylum and a new species of diatoms from the Cretaceous and Paleogene deposits of the west Siberian lowlands; Sukhov, S. V., The Upper Paleozoic vegetation from the D'yavol'skaya River in the Tunguss basin; Muromtseva, V. A., Representatives of the Grammysiidae Fischer family in the Lower Carboniferous deposits of western Siberia and east Kazakhstan; Reshetnikova, M. A., The study of the fresh-water ostracods of the Upper Paleozoic coal measures in Karaganda basin; Sergiyenko, A. A., The discovery of Grossilepis aff. tuberculata (Gross) in the Upper Devonian deposits of the Minusinsk depression; Sargiyenko, A. A., A new species of Bothriolepis extensa sp. from the Tubinsk formations in the Minusinsk depression; Krasnov, V. I., The facies alterations of the Beyskian sediments in the south Minusinsk depression; Mironova, N. V., The tabulate corals and heliolitides of the Tom'-Chumyshian (ostracod) beds of Salair; Mironova, N. V., A new phylum of tabulate corals of the caenitid family; Ivanovskiy, A. B., The phylogeny of the Lykophyllidae Wedekind family, Ivanovskiy, A. B., Certain Streptelasmatida of the Middle and Upper Ordovician from the Podkamennaya Tunguska River; Yegorova, L. I., Lower Cambrian trilobites from the Katun' River basin (Gornyy Altay); Semenova, V. S., Certain trilobites from the Ordovician and Silurian in Gornyy Altay; Krasnopeyeva, P. S., New archaeocyatheans from the Obruchevian beds in the Altay-Sayan region.

Same. vyp. 17, 201 pp. Contents: Rostovtsev, N. N., The conditions of gas deposit formation in the Berezovsk region of the west Siberian lowland; Gurari, F. G., Oil and gas prospecting in the Mesozoic formations of the west Siberian lowland; Markevich, V. P., The "active terrace" of the platforms and its importance for the evaluation of the petroleum potentialities of the platforms; Nesterov, I. I., The genesis and the development history of the structures in the Berezovsk region of the west Siberian lowland; Yekhanin, Ye. V., and V. P. Zhdanova, The methods of quantitative investigation of the tectonic of the third-order structures in the west Siberian lowland based on seismic survey data; Karatayev, G. I., and Kh. S. Akhmyatzhanov, The utilization of the anomalous geophysical fields in studying the tectonics of the sedimentary mantle of the west Siberian lowland; Zagorodnov, A. M., and N. M. Smirnov, The problem of the tectonic structure of Tom'-Yaysk interfluve; Telyakova, Z. Kh., Materials on the geology and geomorphology of the Kulunda steppe; Telezhenko, V. P., The method of seismic simulation; Zhero, O. G., The acquifer properties of the sandstones of the Kuzbas Paleozoic deposits; Prozorovich, G. E., The lithology of the Jurassic and Lower Cretaceous deposits in the Turukhansk test hole; Gurova, T. I., The sorting problem in the Mesozoic and Cenozoic terrigenous rocks in the west Siberian lowland; Romodina, L. I., The correlation of the Upper Cretaceous sections of the Yeniseyan region on the west Siberian lowland according to the typomorphic characteristics of minerals; Sorokina, Ye. G., The stages of Cretaceous deposition in the central Ob' regions; Antonova, T. F., and T. I. Gurova, The problem of the mineralogical composition of the Mesozoic clays in the west Siberian lowland; Perozio, G. N., The epigenetic alterations in the Mesozoic terrigenous rocks in the west Siberian lowland; Sadikov, M. A., Experience in determining the mineralization of stratal water in the northeastern part of the west Siberian lowland on the basis of electric logging.

21. Trudy Tsentralnogo nauchno-issledovatel'skogo gormorazvodochnogo institute. [Transactions of the Central Mineral Prospecting Scientific Research Institute]: vyp. 40, M., 1961, 161 pp. Contents: Borodayevskaya, M. B., and N. A. Perizhnyak, Localization conditions of the pyrite mineralization within the limits of the Sibaysk ore field (Southern Urals); Petrovskaya, N. V., The associations of ore-forming minerals, the structural features of orebodies, and certain genetic characteristics of the Sibaysk copper-pyrite deposits (Southern Urals); Storozhenko, A. A., The fenitization process and the fenites developed in the vicinity of the Oktyabr'sk alkaline massif (Ukraine); Kurbanov, A. Sh., Some metalogenetic problems of the Northern Caucasus; Bindeman, N. N., Cases of the post-magmatic manifestation of mineralization associated with the gas daitremes in eastern Transbaykalia.

CHRONICLE

GENERAL MEETING OF THE DIVISION OF GEOLOGICAL AND GEOGRAPHICAL SCIENCES, U. S. S. R. ACADEMY OF SCIENCES, MAY 17, 1962[1]

After the opening remarks made by the Academician D. I. Shcherbakov, Secretary of the Division, a report was presented at the General Meeting of the Division of Geological and Geographical Sciences by I. I. Gorskiy, Associate Member of the U. S. S. R. Academy of Sciences and the Deputy-Secretary of the Division, concerning steps to be taken to comply with the Resolution of the Soviet Communist Party Central Committee and the Council of Ministers of the U. S. S. R. of April 3, 1961 on "Measures to improve the coordination of the scientific-research work in the country and the activity of the U. S. S. R. Academy of Sciences".

The report stimulated a general exchange of opinions and the meeting adopted resolutions aimed at improving the organization of work in the scientific institutions of the U. S. S. R. Academy of Sciences.

Reports were then heard from the departmental directors of the Division on the commitments made by the Institutes of the Division of Geological and Geographical Sciences on the occasion of the 22nd Congress of the U. S. S. R. Communist Party.

IN THE NATIONAL COMMITTEE OF GEOLOGISTS OF THE U. S. S. R.[2]

On Preparations for the 22nd Session of the International Geological Congress

The National Committee of Geologists of the U. S. S. R. announced that, in compliance with decisions made at the 21st Session of the Inter national Geological Congress (Copenhagen, 1960), the 22nd Session of the Congress will be held in India in 1964.

The forthcoming session of the Internationa Geological Congress will be of great importan in the development of geologic science. In vie of this, it is necessary that Soviet geologists should duly prepare themselves for the occasi in order to present to the Congress scientific papers, geologic maps, monographs and other studies characterizing the achievements and th level of geological research in the U. S. S. R.

At the 21st Session of the Congress, Soviet geologists presented many reports and scientific papers on fundamental theoretical prob lems. More than 400 papers and scientific articles were published in 24 symposia publis especially for the Congress. Many reports we included in the Transactions of the Congress.

Demonstrated at the Congress were geologi paleogeographic, tectonic, and metallogenic maps compiled by our geologists, internationa tectonic maps and a map of coal formations in Europe prepared in the U. S. S. R. under the guidance of Soviet geologists, and also numer scientific works published in the U. S. S. R. in recent years.

The National Committee of Geologists of th U. S. S. R. proposes to publish the reports of Soviet geologists for the 22nd session of the Congress by early 1964. In the current year it is necessary to determine the subject matte of the reports, and prepare a list of the monographs and maps that are to be presented at th Congress. All of these materials must be ready for publication by early 1963.

In this connection the National Committee o Geologists of the U. S. S. R. requests the Head of the geological institutions and geologists to submit their suggestions as to the problems they would like to discuss at the Congress. It is desirable that the papers of our geologists should shed some light on actual problems rel tive to the stratigraphy and petrology of the

---

[1]Obshchee sobranie otdeleniya geologo-geograficheskikh nauk Akad. Nauk SSSR, 17 Maya, 1961, (p. 128).

[2]V natsional'nom komitete geologov SSSR, (p. 128).

mbrian, and the stratigraphy of the zoic, Mesozoic and Cenozoic of the ern phyto-geographic provinces, the tec- of mountain structures of interior as well as problems dealing with the al zones of the earth's crust according to gic and geophysical data, the problem of vana land, the absolute age-scale of rocks, le of metamorphism in the formation of its of economic minerals, the geologic ure of the petroliferous provinces of ern U. S. S. R., the geology of the ocean ea bottoms, the problem of arid-zone geology, the theoretical principles and ds of prospecting for deposits of mic minerals, the problem of isotope gy, the theoretical principles of the genesis of commercial minerals based on experimental and other data.

The suggestions received will be considered by the National Committee of Geologists, and appropriate recommendations will be made in accordance with the agenda of the Congress session which will be communicated to us shortly by the Organizing Committee of the Congress in India.

President of the National Committee of Geologists of the U. S. S. R.,

Associate-Member of the U. S. S. R. Academy of Sciences,
I. I. Gorskiy